PVP

Release 0.2.0

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Oct 02, 2020

OVERVIEW

The global COVID-19 pandemic has highlighted the need for a low-cost, rapidly-deployable ventilator, for the current as well as future respiratory virus outbreaks. While safe and robust ventilation technology exists in the commercial sector, the small number of capable suppliers cannot meet the severe demands for ventilators during a pandemic. Moreover, the specialized, proprietary equipment developed by medical device manufacturers is expensive and inaccessible in low-resource areas.

The **People's Ventilator Project (PVP)** is an open-source, low-cost pressure-control ventilator designed for minimal reliance on specialized medical parts to better adapt to supply chain shortages. The **PVP** largely follows established design conventions, most importantly active and computer-controlled inhalation, together with passive exhalation. It supports pressure-controlled ventilation, combined with standard-features like autonomous breath detection, and the suite of FDA required alarms.

Read on here. <overview>

The **People's Ventilator Project (PVP)** is an open-source, low-cost pressure-control ventilator designed for minimal reliance on specialized medical parts to better adapt to supply chain shortages.

CHAPTER

ONE

HARDWARE

The device components were selected to enable a **minimalistic and relatively low-cost ventilator design, to avoid supply chain limitations, and to facilitate rapid and easy assembly**. Most parts in the PVP are not medical-specific devices, and those that are specialized components are readily available and standardized across ventilator platforms, such as standard respiratory circuits and HEPA filters. We provide complete assembly of the PVP, including 3D-printable components, as well as justifications for selecting all actuators and sensors, as guidance to those who cannot source an exact match to components used in the Bill of Materials.

1.1 PVP Hardware

CHAPTER TWO

SOFTWARE

images/gui_overview_v1_1920px.png

PVP's software was developed to bring the philosophy of free and open-source software to medical devices. PVP is not only open from top to bottom, but we have developed it as a framework for **an adaptable, general-purpose, communally-developed ventilator.**

PVP's ventilation control system is fast, robust, and **written entirely in high-level Python** (3.7) – without the development and inspection bottlenecks of split computer/microprocessor systems that require users to read and write low-level hardware firmware.

All of PVP's components are **modularly designed**, allowing them to be reconfigured and expanded for new ventilation modes and hardware configurations.

We provide complete **API-level documentation** and an **automated testing suite** to give everyone the freedom to inspect, understand, and expand PVP's software framework.

2.1 PVP Modules

CHAPTER

THREE

PERFORMANCE

The completed system was tested with a standard test lung (QuickLung, IngMar Medical, Pittsburgh, PA) that allowed testing combinations of three lung compliance settings (C=5, 20, and 50 mL cm H2O) and three airway resistance settings (R=5, 20, and 50 cm H2O/L/s). The figure above shows pressure control performance for midpoint settings: C=20 mL/cm H2O, R=20 cm H2O/L/s, PIP=30 cm H2O, PEEP=5 cm H2O. PIP is reached within a 300 ms ramp period, then holds for the PIP plateau with minimal fluctuation of airway pressure for the remainder of the inspiratory cycle (blue). One the expiratory valve opens, exhalation begins and expiratory flow is measured (orange) as the airway pressure drops to PEEP and remains

there for the rest of the PEEP period.

Some manual adjustment of the pressure waveforms may be warranted depending on the patient, and such adjustment is permitted through a user flow adjustment setting. This flow adjustment setting allows the user to increase the maximum flow rate during the ramp cycle to inflate lungs with higher compliance. The flow setting can be readily changed from the GUI and the control system immediately adapts to the user's input. An example of this flow adjustment is shown in the figure above for four breath cycles. While all cycles reach PIP, the latter two have a higher mean airway pressure, which may be more desirable under certain conditions than the lower mean airway pressure of the former two.

3.1 ISO Standards Testing

In order to characterize the PVP's control over a wide range of conditions, we followed FDA Emergency Use Authorization guidelines, which specify ISO 80601-2-80-2018 for a battery of pressure controlled ventilator standard tests. We tested the conditions that do not stipulate a leak, and present the results here. For each configuration the following parameters are listed: the test number (from the table below), the compliance (C, mL/cm H2O), linear resistance (R, cm H2O/L/s), respiratory frequency (f, breaths/min), peak inspiratory pressure (PIP, cm H2O), positive end-expiratory pressure (PEEP, cm H2O), and flow adjustment setting.

images/single_waveform.png

Fig. 1: Representative pressure control breath cycle waveforms for airway pressure and flow out. Test settings: compliance C=20 mL/cm H2O, airway resistance R=20 cm H2O/L/s, PIP=30 cm H2O, PEEP=5 cm H2O.

images/tune_waveform.png

Table 1: Standard test battery from Table 201.105 in ISO 80601-2-80-2018 for pressure controlled ventilators

Test number	Intended delivered volume (mL)	Compliance (mL (hPa)^-1)	Linear resistance (hPa(L/s)^-1) +/- 10%	Leakage (mL/min) +/- 10%	Ventilatory frequency (breaths/min)	Inspiratory time (s)	Pressure (hPa)	PEEP (hPa)
1	500	50	5	0	20	1	10	5
2	500	50	20	0	12	1	15	10
3	500	20	5	0	20	1	25	5
4	500	20	20	0	20	1	25	10
5	500	50	5	5000	20	1	25	5
6	500	50	20	10000	12	1	25	10
7	300	20	20	0	20	1	15	5
8	300	20	50	0	12	1	25	10
9	300	10	50	0	20	1	30	5
10	300	20	20	3000	20	1	25	5
11	300	20	50	6000	12	1	25	10
12	200	10	20	0	20	1	25	10

These tests cover an array of conditions, and more difficult test cases involve a high airway pressure coupled with a low lung compliance (case nos. 8 and 9). Under these conditions, if the inspiratory flow rate during the ramp phase is too high, the high airway resistance will produce a transient spike in airway pressure which can greatly overshoot the PIP value. For this reason, the system uses a low initial flow setting and allows the clinican to increase the flow rate if necessary.

The PVP integrates expiratory flow to monitor the tidal volume, which is not directly set in pressure controlled ventilation, but is an important parameter. Of the test conditions in the ISO standard, four that we tested intended a nominal delivered tidal volume of 500 mL, three intended 300 mL, and one intended 200 mL. For most cases, the estimated tidal volume has a tight spread clustered within 20% of the intended value.

3.2 Breath Detection

A patient-initiated breath after exhalation will result in a momentary drop in PEEP. PVP may optionally detect these transient decreases to trigger a new pressure-controlled breath cycle. We tested this functionality by triggering numerous breaths out of phase with the intended inspiratory cycle, using a QuickTrigger (IngMar Medical, Pittsburgh, PA) to momentarily open the test lung during PEEP and simulate this transient drop of pressure.

3.3 High Pressure Detection

Above is a demonstration of the PVP's high airway pressure alarm (HAPA). An airway blockage results in a high airway pressure (above 60 cm H2O) that the system corrects within ~500 ms. Test settings: compliance C=20 mL/cm H2O, airway resistance R=20 cm H2O/L/s, PIP=30 cm H2O, PEEP=5 cm H2O.

images/waveform_battery_500mL.png

images/waveform_battery_300mL.png

images/tidal_volumes.png

images/spontaneous_breath.png

images/hapa_demonstration.png

CHAPTER

FOUR

HARDWARE OVERVIEW

The PVP components were selected to enable a **minimalistic and relatively low-cost ventilator design**, to avoid supply chain limitations, and to facilitate rapid and easy assembly. Most parts in the PVP are not medical-specific devices, and those that are specialized components are readily available and standardized across ventilator platforms, such as standard respiratory circuits and HEPA filters. We provide complete assembly of the PVP, including 3D-printable components, as well as justifications for selecting all actuators and sensors, as guidance to those who cannot source an exact match to components used in the Bill of Materials.

4.1 Actuators

- Proportional solenoid valve
- Expiratory valve

4.2 Sensors

- Oxygen sensor
- Proximal pressure sensor
- Expiratory flow sensor

CHAPTER

FIVE

COMPONENTS

The device components were selected to enable a **minimalistic and relatively low-cost ventilator design**, to avoid supply chain limitations, and to facilitate rapid and easy assembly. Most parts in our system are not medical-specific devices, and those that are specialized components are readily available and standardized across ventilator platforms, such as standard respiratory circuits and HEPA filters. Below, we provide justifications for selecting all actuators and sensors as guidance to those who cannot source an exact match to components used in the PVP.

5.1 Hardware Design

The following is a guided walk through the main hardware components that comprise the respiratory circuit, roughly following the flow of gas from the system inlet, to the patient, then out through the expiratory valve.

Hospital gas bleder. At the inlet to the system, we assume the presence of a commercial-off-the-shelf (COTS) gas blender. These devices mix air from U.S. standard medical air and O2 as supplied at the hospital wall at a pressure of around 50 psig. The device outlet fitting may vary, but we assume a male O2 DISS fitting (NIST standard). In field hospitals, compressed air and O2 cylinders may be utilized in conjunction with a gas blender, or a low-cost Venturi-based gas blender. We additionally assume that the oxygen concentration of gas supplied by the blender can be manually adjusted. Users will be able to monitor the oxygen concentration level in real-time on the device GUI.

Fittings and 3D printed adapters. Standardized fittings were selected whenever possible to ease part sourcing in the event that engineers replicating the system need to swap out a component, possibly as the result of sourcing constraints within their local geographic area. Many fittings are American national pipe thread (NPT) standard, or conform to the respiratory circuit tubing standards (15mm I.D./22 mm O.D.). To reduce system complexity and sourcing requirements of specialized adapters, a number of connectors, brackets, and manifold are provided as 3D printable parts. All 3D printed components were print-tested on multiple 3D printers, including consumer-level devices produced by MakerBot, FlashForge, and Creality3D.

Pressure regulator. The fixed pressure regulator near the inlet of the system functions to step down the pressure supplied to the proportional valve to a safe and consistent set level of 50 psi. It is essential to preventing the over-pressurization of the system in the event of a pressure spike, eases the real-time control task, and ensures that down-stream valves are operating within the acceptable range of flow conditions.

Proportional valve. The proportional valve is the first of two actuated components in the system. It enables regulation of the gas flow to the patient via the PID control framework, described in a following section. A proportional valve upstream of the respiratory circuit enables the controller to modify the inspiratory time, and does not present wear limitations like pinch-valves and other analogous flow-control devices. The normally closed configuration was selected to prevent over-pressurization of the lungs in the event of system failure.

Sensors. The system includes an oxygen sensor for monitoring oxygen concentration of the blended gas supplied to the patient, a pressure sensor located proximally to the patient mouth along the respiratory circuit, and a spirometer, consisting of a plastic housing (D-Lite, GE Healthcare) with an attached differential pressure sensor, to measure flow. Individual sensor selection will be described in more detail in a following section. The oxygen sensor read-out is used to adjust the manual gas blender and to trigger alarm states in the event of deviations from a setpoint. The proximal location of the primary pressure sensor was selected due to the choice of a pressure-based control strategy, specifically to ensure the most accurate pressure readings with respect to the patient's lungs. Flow estimates from the single expiratory flow sensor are not directly used in the pressure-based control scheme, but enable the device to trigger appropriate alarm states in order to avoid deviations from the tidal volume of gas leaving the lungs during expiration. The device does not currently monitor gas temperature and humidity due to the use of an HME rather than a heated humidification system.

Pressure relief. A critical safety component is the pressure relief valve (alternatively called the "pressure release valve", or "pressure safety valve"). The proportional valve is controlled to ensure that the pressure of the gas supplied to the patient never rises above a set maximum level. The relief valve acts as a backup safety mechanism and opens if the pressure exceeds a safe level, thereby dumping excess gas to atmosphere. Thus, the relief valve in this system is located between the proportional valve and the patient respiratory circuit. The pressure relief valve we source cracks at 1 psi (approx 70 cm H2O).

Standard repisratory circuit. The breathing circuit which connects the patient to the device is a standard respiratory circuit: the flexible, corrugated plastic tubing used in commercial ICU ventilators. Because this system assumes the use of an HME/F to maintain humidity levels of gas supplied to the patient, specialized heated tubing is not required.

Anti-suffocation check valve. A standard ventilator check valve (alternatively called a "one-way valve") is used as a secondary safety component in-line between the proportional valve and the patient respiratory circuit. The check valve is oriented such that air can be pulled into the system in the event of system failure, but that air cannot flow outward through the valve. A standard respiratory circuit check valve is used because it is a low-cost, readily sourced device with low cracking pressure and sufficiently high valve flow coefficient (Cv).

Bacterial filters. A medical-grade electrostatic filter is placed on either end of the respiratory circuit. These function as protection against contamination of device internals and surroundings by pathogens and reduces the probability of the patient developing a hospital-acquired infection. The electrostatic filter presents low resistance to flow in the airway.

HME. A Heat and Moisture Exchanger (HME) is placed proximal to the patient. This is used to passively humidify and warm air inspired by the patient. HMEs are the standard solution in the absence of a heated humidifier. While we evaluated the use of an HME/F which integrates a bacteriological/viral filter, use of an HME/F increased flow resistance and compromised pressure control.

Pressure sampling filter. Proximal airway pressure is sampled at a pressure port near the wye adapter, and measured by a pressure sensor on the sensor PCB. To protect the sensor and internals of the ventilator, an additional 0.2 micron bacterial/viral filter is placed in-line between the proximal airway sampling port and the pressure sensor. This is also a standard approach in many commercial ventilators.

Expiratory solenoid. The expiratory solenoid is the second of two actuated components in the system. When this valve is open, air bypasses the lungs, thereby enabling the lungs to de-pressurize upon expiration. When the valve is closed, the lungs may inflate or hold a fixed pressure, according to the control applied to the proportional valve. The expiratory flow control components must be selected to have a sufficiently high valve flow coefficient (Cv) to prevent obstruction upon expiration. This valve is also selected to be normally open, to enable the patient to expire in the event of system failure.

Manual PEEP valve. The PEEP valve is a component which maintains the positive end-expiratory pressure (PEEP) of the system above atmospheric pressure to promote gas exchange to the lungs. A typical COTS PEEP valve is a spring-based relief valve which exhausts when pressure within the airway exceeds a fixed limit. This limit is manually adjusted via compression of the spring. Various low-cost alternatives to a COTS mechanical PEEP valve exist, including the use of a simple water column, in the event that PEEP valves become challenging to source. We additionally provide a 3D printable PEEP valve alternative which utilizes a thin membrane, rather than a spring, to maintain PEEP.

5.2 Actuator Selection

When planning actuator selection, it was necessary to consider the placement of the valves within the larger system. Initially, we anticipated sourcing a proportional valve to operate at very low pressures (0-50 cm H20) and sufficiently high flow (over 120 LPM) of gas within the airway. However, a low-pressure, high-flow regime proportional valve is far more expensive than a proportional valve which operates within high-pressure (textasciitilde50 psi), high-flow regimes. Thus, we designed the device such that the proportional valve would admit gas within the high-pressure regime and regulate air flow to the patient from the inspiratory airway limb. Conceivably, it is possible to control the air flow to the patient with the proportional valve alone. However, we couple this actuator with a solenoid and PEEP valve to ensure robust control during PIP (peak inspiratory pressure) and PEEP hold, and to minimize the loss of O2-blended gas to the atmosphere, particularly during PIP hold.

Proportional valve sourcing. Despite designing the system such that the proportional valve could be sourced for operation within a normal inlet pressure regime (approximately 50 psi), it was necessary to search for a valve with a high enough valve flow coefficient (Cv) to admit sufficient gas to the patient. We sourced an SMC PVQ31-5G-23-01N valve with stainless steel body in the normally-closed configuration. This valve has a port size of 1/8" (Rc) and has previously been used for respiratory applications. Although the manufacturer does not supply Cv estimates, we empirically determined that this valve is able to flow sufficiently for the application.

Expiratory valve sourcing. When sourcing the expiratory solenoid, it was necessary to choose a device with a sufficiently high valve flow coefficient (Cv) which could still actuate quickly enough to enable robust control of the gas flow. A reduced Cv in this portion of the circuit would restrict the ability of the patient to exhale. Initially, a number of control valves were sourced for their rapid switching speeds and empirically tested, as Cv estimates are often not provided by valve manufacturers. Ultimately, however, we selected a process valve in lieu of a control valve to ensure the device would flow sufficiently well, and the choice of valve did not present problems when implementing the control strategy. The SMC VXZ250HGB solenoid valve in the normally-open configuration was selected. The valve in particular was sourced partially due to its large port size (3/4" NPT). If an analogous solenoid with rapid switching speed and large Cv cannot be sourced, engineers replicating our device may consider the use of pneumatically actuated valves driven from air routed from a take-off downstream of the pressure regulator.

Manual PEEP valve sourcing. The PEEP valve is one of the few medical-specific COTS components in the device. The system configuration assumes the use of any ventilator-specific PEEP valve (Teleflex, CareFusion, etc.) coupled with an adapter to the standard 22 mm respiratory circuit tubing. In anticipation of potential supply chain limitations, as noted previously, we additionally provide the CAD models of a 3D printable PEEP valve.

5.3 Sensor Selection

We selected a minimal set of sensors with analog outputs to keep the system design sufficiently adaptable. If there were a part shortage for a specific pressure sensor, for example, any readily available pressure sensor with an analog output could be substituted into the system following a simple adjustment in calibration in the controller. Our system uses three sensors: an oxygen sensor, an airway pressure sensor, and a flow sensor with availability for a fourth addition, all interfaced with the Raspberry Pi via a 4-channel ADC (Adafruit ADS1115) through an I2C connection.

Oxygen sensor. We selected an electrochemical oxygen sensor (Sensironics SS-12A) designed for the range of FiO2 used for standard ventilation and in other medical devices. The cell is self-powered, generating a small DC voltage (13-16 mV) that is linearly proportional to oxygen concentration. The output signal is amplified by an instrumentation amplifier interfacing the sensor with the Raspberry Pi controller (see electronics). This sensor is a wear part with a lifespan of about 6 years under operation at ambient air; therefore under continuous ventilator operation with oxygen-enriched gas, it will need to be replaced more frequently. This part can be replaced with any other medical O2 sensor provided calibration is performed given that these parts are typically sold as raw sensors, with a 3-pin molex interface. Moreover, the sensor we specify is compatible with a range of medical O2 sensors, including the Analytical Industries PSR-11-917-M or the Puritan Bennett 4-072214-00, so we anticipate abundant sourcing options.

Airway pressure sensor. We selected a pressure sensor with a few key characteristics in mind: 1) the sensor had to be compatible with the 5V supply of the Raspberry Pi, 2) the sensor's input pressure range had conform to the range of pressures possible in our device (up to 70 cm H2O, the pressure relief valve's cutoff), and 3) the sensor's response time had to be sufficiently fast. We selected the amplified middle pressure sensor from Amphenol (1 PSI-D-4V), which was readily available, with a measurement range up to 70 cm H2O and an analog output voltage span of 4 V. Moreover, the decision to utilize an analog sensor is convenient for engineers replicating the design, as new analog sensors can be swapped in without extensive code and electronics modifications, as in the case of I2C devices which require modifications to hardware addresses. Other pressure sensors from this Amphenol line can be used as replacements if necessary.

Spirometer. Because flow measurement is essential for measuring tidal volume during pressure-controlled ventilation, medical flow sensor availability was extremely limited during the early stages of the 2020 COVID-19 pandemic, and supply is still an issue. For that reason, we looked for inexpensive, more easily sourced spirometers to use in our system. We used the GE D-Lite spirometer, which is a mass-produced part and has been used in hospitals for nearly 30 years. The D-Lite sensor is inserted in-line with the flow of gas on the expiratory limb, and two ports are used to measure the differential pressure drop resulting from flow through a narrow physical restriction. The third pressure-measurement port on the D-Lite is blocked by a male Luer cap, but this could be used as a backup pressure measurement port if desired. An Amphenol 5 INCH-D2-P4V-MINI was selected to measure the differential pressure across the two D-Lite takeoffs. As with the primary (absolute) pressure sensor, this sensor was selected to conform to the voltage range of the Raspberry Pi, operate within a small pressure range, and have a sufficiently fast response time (partially as a function of the analog-to-digital converter). Also, this analog sensor can be readily replaced with a similar analog sensor without substantial code/electronics modifications.

CHAPTER

SIX

ASSEMBLY

6.1 SoldidWorks Assembly

6.2 3D Printed Parts

- `Sensor atrium manifold - [.stl]`
- `Screen module mount (left) - [.stl]`
- `Screen module mount (right) - [.stl]`
- etc…

6.3 Enclosure

CHAPTER

SEVEN

ELECTRONICS

images/electronics_diagram.png

Fig. 1: PVP block diagram for main electrical components

The PVP is coordinated by a Raspberry Pi 4 board, which runs the graphical user interface, administers the alarm system, monitors sensor values, and sends actuation commands to the valves. The core electrical system consists of two modular PCB ‘hats’, a sensor PCB and an actuator PCB, that stack onto the Raspberry Pi via 40-pin stackable headers. The modularity of this system enables individual boards to be revised or modified to adapt to component substitutions if required.

7.1 Power and I/O

The main power to the systems is supplied by a DIN rail-mounted 150W 24V supply, which drives the inspiratory valve (4W) and expiratory valves (13W). This voltage is converted to 5V by a switched mode PCB-mounted regulated to power the Raspberry Pi and sensors. This power is transmitted across the PCBs through the stacked headers when required.

Table 1: Power and I/O bill of materials

Part	Description
Meanwell 24 V DC Power Supply	DIN Rail Power Supplies 150W 24V 5A EN55022 Class B
Raspberry Pi	Raspberry Pi- Model B-1 (1GB RAM)
USB-C Charger/cable	To power the RPi
Micro SD Card	SanDisk Ultra 32GB MicroSDHC UHS-I Card with Adapter
Raspberry Pi Display	Matrix Orbital: TFT Displays & Accessories 7 in HDMI TFT G Series
HDMI for Display	Display cable: HDMI Cables HDMI Cbl Assbly 1M Micro to STD
Mini USB for Display	Display cable: USB Cables / IEEE 1394 Cables 3 ft Ext A-B Mini USB Cable
Screen mount thumb screws	SCREEN_MOUNT_THUMB_SCREW: Brass Raised Knurled-Head Thumb Screw, 1/4"-20 Thread Size, 1/2" Long
Cable grommet	USER_INTERFACE_CABLE_GROMMET: Buna-N Rubber Grommets, for 1-3/8" Hole Diameter and 1/16" Material Thickness, 1" ID, pack of 10
Cable P-clip	USER_INTERFACE_CABLE_P-CLIP_0.375_ID_SS: Snug-Fit Vibration-Damping Loop Clamp, 304 Stainless Steel with Silicone Rubber Cushion, 3/8" ID, pack of 10, 17/64 mounting holes
Keyboard	Adesso: Mini keyboard with trackball

7.2 Sensor PCB

The sensor board interfaces four analog output sensors with the Raspberry Pi via I2C commands to a 12-bit 4-channel ADC (Adafruit ADS1015).

1. an airway pressure sensor (Amphenol 1 PSI-D-4V-MINI)
2. a differential pressure sensor (Amphenol 5 INCH-D2-P4V-MINI) to report the expiratory flow rate through a D-Lite spirometer
3. an oxygen sensor (Sensiron SS-12A) whose 13 mV differential output signal is amplified 250-fold by an instrumentation amplifier (Texas Instruments INA126)
4. a fourth auxiliary slot for an additional analog output sensor (unused)

A set of additional header pins allows for digital output sensors (such as the Sensiron SFM3300 flow sensor) to be interfaced with the Pi directly via I2C if desired.

- `Sensor PCB - [KiCad project .zip]`

images/pressure_rev2_schematic_image.png

Fig. 2: Sensor PCB schematic

Table 2: Sensor PCB bill of materials

Ref	Part	Purpose
J1	40-pin stackable RPi header	Connects board to RPi
J2	4-pin 0.1" header	I2C connector if desired
J3	2-pin 0.1" header	Connects ALRT pin from ADS1115 to RPi if needed
J4	3-pin 0.1" header or 3 pin fan extension cable	Connects board to oxygen sensor
R1	330 Ohm resistor	Sets gain for INA126
C1	10 uF, 25V	Cap for TL7660
C2	10 uF, 25V	Cap for TL7660
U1	TL7660, DIP8	Rail splitter for INA126
U2	INA126, DIP8	Instrumentation amplifier for oxygen sensor output
U3	Amphenol 5 INCH-D2-P4V-MINI	Differential pressure sensor (for flow measurement)
U4	Adafruit ADS1115	4x 12-bit ADC
U5	Amphenol 1 PSI-D-4V-MINI	Airway pressure sensor
U6		Auxiliary analog output sensor slot

7.3 Actuator PCB

The purpose of the actuator board is twofold:

1. regulate the 24V power supply to 5V (CUI Inc PDQE15-Q24-S5-D DC-DC converter)
2. interface the Raspberry Pi with the inspiratory and expiratory valves through an array of solenoid drivers (ULN2003A Darlington transistor array)

- `Actuator PCB - [KiCad project .zip]`

Table 3: Actuator PCB bill of materials

Ref	Part	Purpose
J2	2-pin screw terminal, 5.08 mm pitch, PCB mount	Connects to 24V supply
J3	2-pin screw terminal, 5.08 mm pitch, PCB mount	Connects to on/off expiratory valve
J4	2-pin screw terminal, 5.08 mm pitch, PCB mount	Connects to inspiratory valve, driven by PWM
J5	40-pin stackable RPi header	Connects board to RPi
J6	2-pin 0.1" header	Jumper between 5V and Raspberry Pi
C1	100 uF, 16V	5V rail filter cap
C2	6.8 uF, 50V	24V rail filter cap
C3	6.8 uF, 50V	24V rail filter cap
U1	ULN2003A	Darlington BJT array to drive solenoids
U2	CUI PDQ15-Q24-S5-D	24-to-5V DC-DC converter

images/actuators_rev2_schematic_image.png

Fig. 3: Actuator PCB schematic

CHAPTER

EIGHT

BILL OF MATERIALS

- Bill of materials - [.csv]

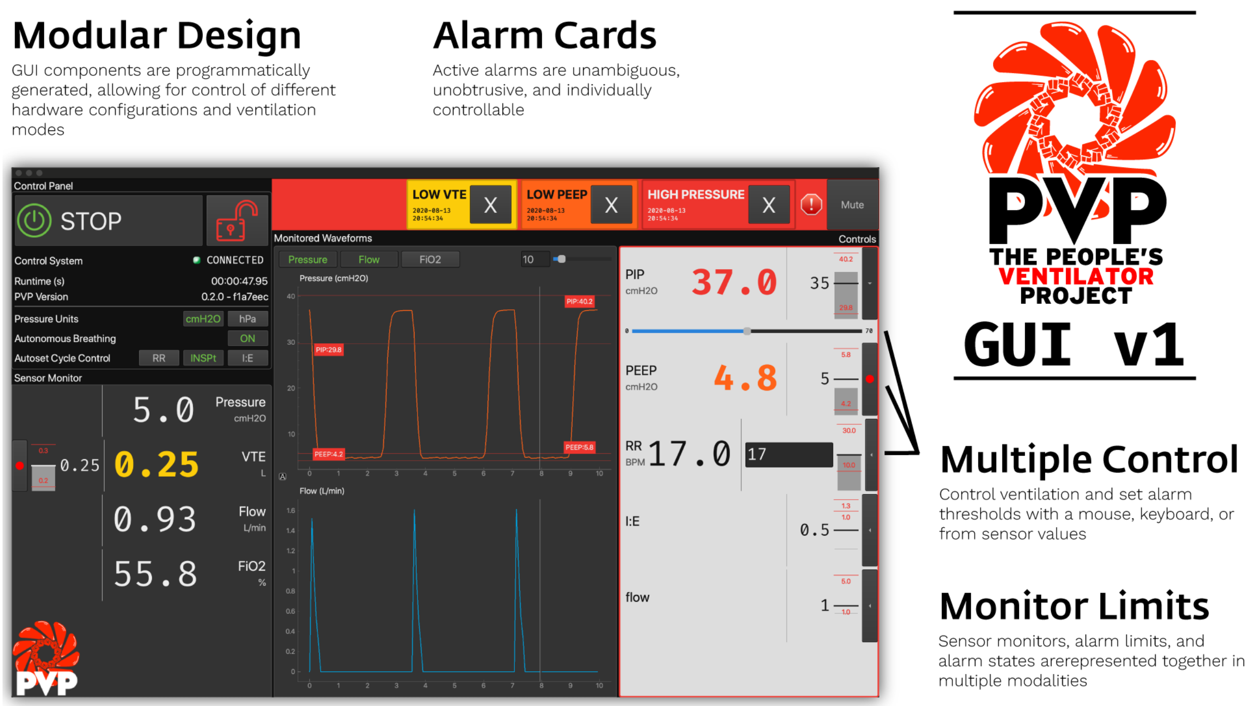
Component	Description
I/O	
Raspberry Pi	Raspberry Pi- Model B-1 (1GB RAM)
USB-C Charger/cable	To power the RPi
Micro SD Card	SanDisk Ultra 32GB MicroSDHC UHS-I Card with Adapter
7” Display	Lilliput 779GL-70NP/C/T - 7” HDMI Capacitive Touchscreen monitor
Screen Mount	Lilliput Monitor Stand
HDMI for Display	Display cable: HDMI Cables HDMI Cbl Assbly 1M Micro to STD
Mini USB for Display	Display cable: USB Cables / IEEE 1394 Cables 3 ft Ext A-B Mini USB Cable
Cable grommet	USER_INTERFACE_CABLE_GROMMET: Buna-N Rubber Grommets, for 1-3/8”
Cable P-clip	USER_INTERFACE_CABLE_P-CLIP_0.375_ID_SS: Snug-Fit Vibration-Damping
Keyboard	Adesso: Mini keyboard with trackball
	AC Power Cable
Airway Components	
	CUSTOM_ID_RUBBER_GROMMET_FOR_0.5_HOLE_0.0625_MATL: Cut-to-Si
Oxygen DISS to 3/8” NPT Adapter	(Not specified in assembly)
Inlet manifold	1023N150_MANIFOLD_0.375_NPT_IN_0.25NPT_OUT : Straight-Flow Rectangu
1/4” NPT Connector (male/male)	PIPE_STUB_0.25_NPT_SS_W_SEALANT: Standard-Wall 304/304L Stainless Ste
Teflon tape	PTFE thread sealant tape (1/2”)
Manifold plug 1/4” NPT	MANIFOLD_PLUG_0.25_NPT_SS: High-Pressure 347 Stainless Steel Pipe Fitting
Hex nuts	LN_10-32_STAINLESS_18-8: 18-8 Stainless Steel Hex Nut, 10-32 Thread Size, pa
Manifold washers	W_10_NARROW_0.406OD_316_SS: 18-8 Stainless Steel Washer for Soft Material
Fixed pressure regulator	Fixed-Pressure Compressed Air Regulator (with two plugs) , 50 psi
Push-to-connect: 1/4” NPT	PUSH_CONNECT_8MM_0.25_NPTM: 1/4” NPT to push-to-connect 8mm tubing
Pneumatic Tubing	Polyurethane tubing: Firm Polyurethane Rubber Tubing for Air and Water, 5 mm ID
Push-to-connect: 1/8” BSPT	PUSH_CONNECT_FITTING_8MM_TO_0.125_BPST: Push-to-Connect Tube Fitti
Insp proportional valve	SMC PVQ31-5G-23-01N-H valve, proportional, PVQ PROPORTIONAL VALVE
Push-to-connect: Inline T-adapter to 1/4” NPT	PUSH_CONNECT_T_8MM_0.25_NPT: Push-to-Connect Tube Fitting for Air, Inlin
1/4” NPT Connector (female/female)	NPTF_0.25_X_0.25_NPTF_COUPLER: CPVC Pipe Fitting for Hot Water, Straight
Pressure release valve	Compact Nylon Pressure-Relief Valve for Air, 1 psi, 1/4 NPT Male
Oxygen sensor	O2 Sensor, SS-12A (or equivalents, e.g. Analytical Industries PSR-11-917-M)
Emergency breathing (check) valve	Teleflex Medical One Way Valve

Component	Description
DAR filters	DAR Electrostatic filters - Large (10x) (NEED A PRESCRIPTION TO ORDER)
Adult Respiratory Circuit w Humidifier Limb	Standard resp. circuit
	Adapter / filter to connect gas sampling lines to proximal side - TOM
Gas sampling line	Gas Sampling Line McKesson 16-GSL Each/1 (x3)
Luer lock connector	Sensit Luer Lock Connector from Grainger
Luer lock filter	Luer lock filter 0.2um from Promepla
Pressure sensor (for Paw)	1 PSI-D-4V-MINI
Tubing connectors	Flexible Connector (Silicone Rubber) 22mm I.D. X 22mm I.D. (x6)
Flow sensor	Disposable GE D-Lite flow sensor
Luer plug	Plastic Quick-Turn Tube Coupling, Nylon Plastic Caps for Plugs
Differential pressure sensor for flow	5 INCH-D2-P4V-MINI
3/4" NPT Connector (male/male)	Thick-Wall Polypropylene Pipe Fitting for Chemicals, Connector with Hex Body, 3/
Exp solenoid valve	SMC VXZ250HGB valve, 20A, NORMALLY OPEN, C37, Port 3/4 (NPT), Orifice
Exp solenoid brackets	T-Slotted Framing, Silver Flush 90 Degree Angle Bracket for 1" High Rail
Framing/Structural Components	
80/20 (x4)	T-Slotted Framing, Single 4-Slot Rail, Silver, 1" High x 1" Wide, Solid, 3' Long - 4x
80/20 gusset bracket (x18)	Silver Gusset Bracket, 1" Long for 1" High Rail T-Slotted Framing x18
80/20 rail (x6)	T-Slotted Framing, Single 4-Slot Rail, Silver, 1" High x 1" Wide, Solid, 1' Long x6
80/20 button head nuts (packs of 25, x2)	End-feed single nuts for T-Slotted framing: T-Slotted Framing, End-Feed Single Nut
Button-head hex screws, pack of 50	BHCS_0.25-20x0.412_SS: 18-8 Stainless Steel Button Head Hex Drive Screw, 1/4"-
Socket head screw, pack of 100	SHCS_M3_X_0.5_6MM_SS: 18-8 Stainless Steel Socket Head Screw, M3 x 0.5 mm
Button head screws (long), pack of 10	BHCS_10-32_X_2_SS: 18-8 Stainless Steel Button Head Hex Drive Screw, 10-32 T
Button head screws (short), pack of 25	BHCS_M6_X_1_8MM_SS: Button Head Hex Drive Screw, Passivated 18-8 Stainles
HDPE sheeting	Moisture-Resistant HDPE Sheet, 12" x 48" x 1/16"
Lifting handle	LIFTING_HANDLE: Oval Pull Handle, Unthreaded Hole, Black Aluminum, 4-9/16
Screws for lifting handle	SHCS_0.25-20x0.75_Gr8_ASTM_F1136, pack of 50
Leveling mount (4 feet)	TLA_LEVELING_MOUNT: Light Duty Leveling Mount, 1" Long 1/4"-20 Threade
Nuts for leveling mount	LN_THIN_0.25-20_STAINLESS: 18-8 Stainless Steel Thin Hex Nut, 1/4"-20 Threa
PETG for 3d printing	~1 kg spool of PETG
Electronics	
Standoffs	Standoffs & Spacers 4.5 HEX 12.0mm ALUM
Meanwell DC Power Supply	DIN Rail Power Supplies 150W 24V 5A EN55022 Class B
DIN Rail	Aluminum DIN 3 Rail, 10mm Deep, 1m Long
DIN washers	W_0.25_FLAT_THICK_GR8_YELLOW_ZINC: Zinc Yellow-Chromate Plated Stee
Sensor board (excluding pressure sensors)	
2-layer PCB	Advanced Circuits 2 layer board
12-bit ADC	Adafruit Data Conversion IC Development Tools ADS1015 Breakout 12-Bit ADC
Voltage splitter U1	TL7660, 8-DIP package
Instrumentation amplifier U2	INA126PA, 8-DIP package
R3, sensor	
40 pin Pi header J1	Raspberry pi 40 pin stacking header
4x1 header J2	male pin header 1x04 P2.54mm
2x1 header J3	male pin header 1x02 P2.54mm
Oxygen sensor cable (J4)	3 pin fan cable extension, 36", ribbon style
330 Ohm resistor R1	330 Ohm resistor, through hole, 1/4 Watt
Capacitors C1,C2	10 uF, 25V, electrolytic radial
Actuator board	

Component	Description
2-layer PCB	Advanced Circuits 2 layer board
5V DC/DC Converter	490-PDQE15-Q24-S5-D
Darlington array U1	ULN2003AN IC PWR RELAY 7NPN 1:1 16DIP
40 pin Pi header J1	Raspberry pi 40 pin stacking header
Screw terminals J2, J3, J4	5.08 mm pitch 2-pin screw terminal block connector, PCB mount
2x1 header J5	male pin header 1x02 P2.54mm
Capacitor C1	100 uF, 16V, electrolytic radial
Capacitors C2,C3	6.8 uF, 50V, electrolytic radial
Speaker	Logitech Z50 speaker
Specialized Tools	
M16 tap	HSS Tap, Bottoming Chamfer, M16 x 1.0 mm Thread (for mounting O2 Sensor)
1/4” NPT tap	Uncoated High-Speed Steel Pipe and Conduit Thread Tap High-Speed Steel, Plug Cl
3/4” NPT tap	Uncoated High-Speed Steel Pipe and Conduit Thread Tap: High-Speed Steel, Plug C
Ingmar QuickLung Test Bellows	(Optional) variable resistance/compliance test lung for testing only
Not on the List:	
PETG for 3d printing	~1 kg spool of PETG
Commercial PEEP valves	Alternative: Medium silicone film for printed PEEP valve: https://www.mcmaster.cc
Adult Test Lung	Standard adult test lung (Many options here)
Air compressor for initial testing	

Component	Description

SOFTWARE OVERVIEW



PVP is modularly designed to facilitate future adaptation to new hardware configurations and ventilation modes. APIs were designed for each of the modules to a) make them easily inspected and configured and b) make it clear to future developers how to adapt the system to their needs.

PVP runs as multiple independent processes The GUI provides an interface to control and monitor ventilation, and the controller process handles the ventilation logic and interfaces with the hardware. Inter-process communication is mediated by a coordinator module via xml-rpc. Several 'common' modules facilitate system configuration and constitute the inter-process API. We designed the API around a uni-fied, configurablevaluesmodule that allow the GUI andcontroller to be reconfigured while also ensuring system robustness and simplicity.

- The *GUI* and *Coordinator* run in the first process, receive user input, display system status, and relay `ControlSetting` s to the *Controller* .
- At launch, the *Coordinator* spawns a *Controller* that runs the logic of the ventilator based on control values from the GUI.
- The *Controller* communicates with a third pigpiod process which communicates with the ventilation hardware

PVP is configured by

- The *Values* module parameterizes the different sensor and control values displayed by the GUI and used by the controller
- The *Prefs* module creates a `prefs.json` file in `~/pvp` that defines user-specific preferences.

PVP is launched like:

```
python3 -m pvp.main
```

And launch options can be displayed with the `--help` flag.

9.1 PVP Modules

CHAPTER

TEN

GUI

10.1 Main GUI Module

Classes:

`Alarm`(alarm_type, severity, start_time, . . .)	Representation of alarm status and parameters
`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
`Alarm_Manager`()	The Alarm Manager
`ControlSetting`(name, value, min_value, . . .)	Message containing ventilation control parameters.
`CoordinatorBase`([sim_mode])	
`PVP_Gui`(coordinator, set_defaults, update_period)	The Main GUI window.
`SensorValues`([timestamp, loop_counter, . . .])	Structured class for communicating sensor readings throughout PVP.
`ValueName`(value)	Canonical names of all values used in PVP.

Functions:

`get_gui_instance`()	Retreive the currently running instance of the GUI
`init_logger`(module_name[, log_level, . . .])	Initialize a logger for logging events.
`launch_gui`(coordinator[, set_defaults, . . .])	Launch the GUI with its appropriate arguments and doing its special opening routine
`mono_font`()	module function to return a `PySide2.QtGui.QFont` to use as the mono font.
`set_gui_instance`(instance)	Store the current instance of the GUI

class pvp.gui.main.**PVP_Gui**(*coordinator: pvp.coordinator.coordinator.CoordinatorBase, set_defaults: bool = False, update_period: float = 0.05, screenshot=False*)

The Main GUI window.

Creates 5 sets of widgets:

- A `Control_Panel` in the top left corner that controls basic system operation and settings
- A `Alarm_Bar` along the top that displays active alarms and allows them to be dismissed or muted
- A column of `Display` widgets (according to `values.DISPLAY_MONITOR`) on the left that display sensor values and control their alarm limits
- A column of `Plot` widgets (according to `values.PLOTS`) in the center that display waveforms of sensor readings

- A column of *Display* widgets (according to *values.DISPLAY_CONTROL*) that control ventilation settings

Continually polls the coordinator with *update_gui()* to receive new *SensorValues* and dispatch them to display widgets, plot widgets, and the alarm manager

Note: Only one instance can be created at a time. Uses set_gui_instance() to store a reference to itself. after initialization, use *get_gui_instance* to retrieve a reference.

Parameters

- **coordinator** (*CoordinatorBase*) – Used to communicate with the *ControlModuleBase* .
- **set_defaults** (*bool*) – Whether default *Value* s should be set on initialization (default False) – used for testing and development, values should be set manually for each patient.
- **update_period** (*float*) – The global delay between redraws of the GUI (seconds), used by *timer* .
- **screenshot** (*bool*) – Whether alarms should be manually raised to show the different alarm severities, only used for testing and development and should never be used in a live system.

monitor

Dictionary mapping *values.DISPLAY_MONITOR* keys to widgets.Display objects

Type dict

controls

Dictionary mapping *values.DISPLAY_CONTROL* keys to widgets.Display objects

Type dict

plot_box

Container for plots

Type Plot_Box

coordinator

Some coordinator object that we use to communicate with the controller

Type *pvp.coordinator.coordinator.CoordinatorBase*

alarm_manager

Alarm manager instance

Type *Alarm_Manager*

timer

Timer that calls *PVP_Gui.update_gui()*

Type PySide2.QtCore.QTimer

running

whether ventilation is currently running

Type bool

locked

whether controls have been locked

Type bool

start_time
Start time as returned by `time.time()`

Type float

update_period
The global delay between redraws of the GUI (seconds)

Type float

logger
Logger generated by *loggers.init_logger()*

Attributes:

CONTROL	
MONITOR	
PLOTS	
control_width	
controls_set	Check if all controls are set
gui_closing(*args, **kwargs)	
monitor_width	
plot_width	
state_changed(*args, **kwargs)	
staticMetaObject	
total_width	
update_period	The global delay between redraws of the GUI (seconds)

Methods:

_screenshot()	Raise each of the alarm severities to check if they work and to take a screenshot
_set_cycle_control(value_name, new_value)	Compute the computed breath cycle control.
closeEvent(event)	Emit *gui_closing* and close!
handle_alarm(alarm)	Receive an *Alarm* from the *Alarm_Manager*
init_controls()	on startup, set controls in coordinator to ensure init state is synchronized
init_ui()	0. Create the UI components for the ventilator screen
init_ui_controls()	4. Create the "controls" column of `widgets.Display` widgets
init_ui_monitor()	2. Create the left "sensor monitor" column of `widgets.Display` widgets

continues on next page

Table 4 – continued from previous page

`init_ui_plots()`	3. Create the *Plot_Container*
`init_ui_signals()`	5. Connect Qt signals and slots between widgets
`init_ui_status_bar()`	1. Create the `widgets.Control_Panel` and `widgets.Alarm_Bar`
`limits_updated(control)`	Receive updated alarm limits from the *Alarm_Manager*
`load_state(state)`	Load GUI state and reconstitute
`save_state()`	Try to save GUI state to `prefs['VENT_DIR"] + prefs['GUI_STATE_FN']`
`set_breath_detection(breath_detection)`	Connected to `breath_detection_button` - toggles autonomous breath detection in the controller
`set_control(control_object)`	Set a control in the alarm manager, coordinator, and gui
`set_pressure_units(units)`	Select whether pressure units are displayed as “cmH2O” or “hPa”
`set_value(new_value[, value_name])`	Set a control value using a value and its name.
`start()`	Click the `start_button`
`toggle_cycle_widget(button)`	Set which breath cycle control is automatically calculated
`toggle_lock(state)`	Toggle the lock state of the controls
`toggle_start(state)`	Start or stop ventilation.
`update_gui([vals])`	**param vals** Default None, but SensorValues can be passed manually – usually for debugging
`update_state(state_type, key, val)`	Update the GUI state and save it to disk with `Vent_Gui.save_state()`

gui_closing (**args*, ***kwargs*) **= <PySide2.QtCore.Signal object>**
`PySide2.QtCore.Signal` emitted when the GUI is closing.

state_changed (**args*, ***kwargs*) **= <PySide2.QtCore.Signal object>**
`PySide2.QtCore.Signal` emitted when the gui is started (True) or stopped (False)

MONITOR = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Value object>), (<ValueN
Values to create *Display* widgets for in the Sensor Monitor column. See *values.DISPLAY_MONITOR*

CONTROL = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Value object>), (<ValueN
Values to create *Display* widgets for in the Control column. See *values.CONTROL*

PLOTS = OrderedDict([(<ValueName.PRESSURE: 10>, <pvp.common.values.Value object>), (<Va
Values to create *Plot* widgets for. See *values.PLOTS*

monitor_width = 3
Relative width of the sensor monitor column

plot_width = 4

Relative width of the plot column

control_width = 3
Relative width of the control column

total_width = 10
computed from `monitor_width+plot_width+control_width`

update_gui (*vals: pvp.common.message.SensorValues = None*)

Parameters **vals** (`SensorValue`) – Default None, but SensorValues can be passed manually – usually for debugging

init_ui ()

0. Create the UI components for the ventilator screen

Call, in order:

- *PVP_Gui.init_ui_status_bar()*
- *PVP_Gui.init_ui_monitor()*
- *PVP_Gui.init_ui_plots()*
- *PVP_Gui.init_ui_controls()*
- *PVP_Gui.init_ui_signals()*

Create and set sizes of major layouts

init_ui_status_bar ()

1. Create the `widgets.Control_Panel` and `widgets.Alarm_Bar`

and add them to the main layout

init_ui_monitor ()

2. Create the left "sensor monitor" column of `widgets.Display` widgets

And add the logo to the bottom left corner if there's room

init_ui_plots ()

3. Create the *Plot_Container*

init_ui_controls ()

4. Create the "controls" column of `widgets.Display` widgets

init_ui_signals ()

5. Connect Qt signals and slots between widgets

- Connect controls and sensor monitors to *PVP_Gui.set_value()*
- Connect control panel buttons to their respective methods

set_value (*new_value, value_name=None*)
Set a control value using a value and its name.

Constructs a *message.ControlSetting* object to give to *PVP_Gui.set_control()*

Note: This method is primarily intended as a means of responding to signals from other widgets, Other cases should use *set_control()*

Parameters

- **new_value** (*float*) – A new value for some control setting
- **value_name** (*values.ValueName*) – THe ValueName for the control setting. If None, assumed to be coming from a *Display* widget that can identify itself with its objectName

set_control (*control_object: pvp.common.message.ControlSetting*)

Set a control in the alarm manager, coordinator, and gui

Also update our state with update_state()

Parameters control_object (*message.ControlSetting*) – A control setting to give to CoordinatorBase.set_control

handle_alarm (*alarm: pvp.alarm.alarm.Alarm*)

Receive an *Alarm* from the *Alarm_Manager*

Alarms are both raised and cleared with this method – there is no separate "clear_alarm" method because an alarm of *AlarmSeverity* of OFF is cleared.

Give the alarm to the *Alarm_Bar* and update the alarm *Display.alarm_state* of all widgets listed as Alarm.cause

Parameters alarm (*Alarm*) – The alarm to raise (or clear)

limits_updated (*control: pvp.common.message.ControlSetting*)

Receive updated alarm limits from the *Alarm_Manager*

When a value is set that has an *Alarm_Rule* that *Alarm_Rule.depends* on it, the alarm thresholds will be updated and handled here.

Eg. the high-pressure alarm is set to be 15% above PIP. When PIP is changed, this method will receive a *message.ControlSetting* that tells us that alarm threshold has changed.

Update the *Display* and *Plot* widgets.

If we are setting a new HAPA limit, that is also sent to the controller as it needs to respond as quickly as possible to high-pressure events.

Parameters control (*message.ControlSetting*) – A ControlSetting with its max_value or

:param min_value set:

start ()

Click the start_button

toggle_start (*state: bool*)

Start or stop ventilation.

Typically called by the PVP_Gui.control_panel.start_button.

Raises a dialogue to confirm ventilation start or stop

Starts or stops the controller via the coordinator

If starting, locks controls.

Parameters state (*bool*) – If True, start ventilation. If False, stop ventilation.

closeEvent (*event*)

Emit *gui_closing* and close!

Kill the coordinator with *CoordinatorBase.kill()*

toggle_lock (*state*)
Toggle the lock state of the controls

Typically called by `PVP_Gui.control_panel.lock_button`

Parameters **state** –

Returns:

update_state (*state_type: str, key: str, val: Union[str, float, int]*)
Update the GUI state and save it to disk with `Vent_Gui.save_state()`

Currently, just saves the state of control settings.

Parameters

- **state_type** (*str*) – What type of state to save, one of `('controls')`
- **key** (*str*) – Which of that type is being saved (eg. if 'control', 'PIP')
- **val** (*str, float, int*) – What is that item being set to?

Returns:

save_state ()
Try to save GUI state to `prefs['VENT_DIR"] + prefs['GUI_STATE_FN']`

load_state (*state: Union[str, dict]*)
Load GUI state and reconstitute

currently, just `PVP_Gui.set_value()` for all previously saved values

Parameters **state** (*str, dict*) – either a pathname to a state file or an already-loaded state dictionary

staticMetaObject = <PySide2.QtCore.QMetaObject object>

toggle_cycle_widget (*button*)
Set which breath cycle control is automatically calculated

The timing of a breath cycle can be parameterized with Respiration Rate, Inspiration Time, and Inspiratory/Expiratory ratio, but if two of these parameters are set the third is already known.

This method changes which value has its `Display` widget hidden and is automatically calculated

Parameters **button** (`PySide2.QtWidgets.QAbstractButton`, `values.ValueName`) – The Qt Button that invoked the method or else a ValueName

set_pressure_units (*units*)
Select whether pressure units are displayed as "cmH2O" or "hPa"

calls `Display.set_units()` on controls and plots that display pressure

Parameters **units** (*str*) – one of "cmH2O" or "hPa"

set_breath_detection (*breath_detection: bool*)
Connected to `breath_detection_button` - toggles autonomous breath detection in the controller

Parameters **breath_detection** (*bool*) – Whether the controller detects autonomous breaths and resets the breath cycle accordingly

_set_cycle_control (*value_name: str, new_value: float*)
Compute the computed breath cycle control.

We only actually have BPM and INSPt as controls, so if we're using I:E ratio we have to compute one or the other.

Computes the value and calls *set_control()* with the appropriate values:

```
# ie = inspt/expt
# inspt = ie*expt
# expt = inspt/ie
#
# cycle_time = inspt + expt
# cycle_time = inspt + inspt/ie
# cycle_time = inspt * (1+1/ie)
# inspt = cycle_time / (1+1/ie)
```

property controls_set
Check if all controls are set

Note: Note that even when RR or INSPt are autocalculated, they are still set in their control objects, so this check is the same regardless of what is set to autocalculate

property update_period
The global delay between redraws of the GUI (seconds)

init_controls()
on startup, set controls in coordinator to ensure init state is synchronized

_screenshot()
Raise each of the alarm severities to check if they work and to take a screenshot

Warning: should never be used except for testing and development!

pvp.gui.main.**launch_gui**(*coordinator*, *set_defaults=False*, *screenshot=False*) → Tuple[PySide2.QtWidgets.QApplication, *pvp.gui.main.PVP_Gui*]
Launch the GUI with its appropriate arguments and doing its special opening routine

To launch the gui, one must:

- Create a `PySide2.QtWidgets.QApplication`
- Set the app style using `gui.styles.DARK_THEME`
- Set the app palette with *gui.styles.set_dark_palette()*
- Call the gui's `show` method

Parameters

- **coordinator** (*coordinator.CoordinatorBase*) – Coordinator used to communicate between GUI and controller
- **set_defaults** (*bool*) – whether default control parameters should be set on startup – only to be used for development or testing
- **screenshot** (*bool*) – whether alarms should be raised to take a screenshot, should never be used on a live system.

Returns The `PySide2.QtWidgets.QApplication` and *PVP_Gui*

Return type (tuple)

10.2 GUI Widgets

10.2.1 Control Panel

The Control Panel starts and stops ventilation and controls runtime options

Classes:

`Alarm`(alarm_type, severity, start_time, . . .)	Representation of alarm status and parameters
`AlarmType`(value)	An enumeration.
`Control_Panel`()	The control panel starts and stops ventilation and controls runtime settings
`HeartBeat`(update_interval, timeout_dur)	Track state of connection with Controller
`Lock_Button`(*args, **kwargs)	Button to lock and unlock controls
`OnOffButton`(state_labels, str] =, toggled, . . .)	Simple extension of toggle button with styling for clearer 'ON' vs 'OFF'
`QHLine`([parent, color])	with respct to https://stackoverflow.com/a/51057516
`Start_Button`(*args, **kwargs)	Button to start and stop Ventilation, created by *`Control_Panel`*
`StopWatch`(update_interval, *args, **kwargs)	Simple widget to display ventilation time!
`odict`	alias of `collections.OrderedDict`

Functions:

`get_gui_instance`()	Retreive the currently running instance of the GUI
`mono_font`()	module function to return a `PySide2.QtGui.QFont` to use as the mono font.

class `pvp.gui.widgets.control_panel.`**`Control_Panel`**

The control panel starts and stops ventilation and controls runtime settings

It creates:

- Start/stop button
- **Status indicator - a clock that increments with heartbeats,** or some other visual indicator that things are alright
- Version indicator
- Buttons to select options like cycle autoset and automatic breath detection

Args:

`start_button`

Button to start and stop ventilation

Type *`Start_Button`*

`lock_button`

Button used to lock controls

Type *`Lock_Button`*

`heartbeat`

Widget to keep track of communication with controller

Type *`HeartBeat`*

runtime
Widget used to display time since start of ventilation

Type *StopWatch*

Methods:

`_pressure_units_changed`(button)	Emit the str of the current pressure units
`init_ui`()	Initialize all graphical elements and buttons!

Attributes:

`cycle_autoset_changed`(*args, **kwargs)
`pressure_units_changed`(*args, **kwargs)
`staticMetaObject`

pressure_units_changed(**args, **kwargs*) **= <PySide2.QtCore.Signal object>**
Signal emitted when pressure units have been changed.

Contains str of current pressure units

cycle_autoset_changed(**args, **kwargs*) **= <PySide2.QtCore.Signal object>**
Signal emitted when a different breath cycle control value is set to be autocalculated

init_ui()
Initialize all graphical elements and buttons!

_pressure_units_changed(*button*)
Emit the str of the current pressure units

Parameters **button** (`PySide2.QtWidgets.QPushButton`) – Button that was clicked

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class `pvp.gui.widgets.control_panel.`**Start_Button**(**args, **kwargs*)
Button to start and stop Ventilation, created by *Control_Panel*

pixmaps
Dictionary containing pixmaps used to draw start/stop state

Type dict

Methods:

`load_pixmaps`()	Load pixmaps to *Start_Button.pixmaps*
`set_state`(state)	Set state of button

Attributes:

`states`
`staticMetaObject`

states = ['OFF', 'ON', 'ALARM']
Possible states of Start_Button

load_pixmaps()
Load pixmaps to *Start_Button.pixmaps*

set_state(*state*)
Set state of button

Should only be called by other objects (as there are checks to whether it's ok to start/stop that we shouldn't be aware of)

Parameters **state** (*str*) – one of `('OFF', 'ON', 'ALARM')`

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class `pvp.gui.widgets.control_panel.`**Lock_Button**(**args*, ***kwargs*)
Button to lock and unlock controls

Created by `Control_Panel`

pixmaps
Dictionary containing pixmaps used to draw locked/unlocked state

Type dict

Methods:

`load_pixmaps`()	Load pixmaps used to display lock state to `Lock_Button.pixmaps`
`set_state`(state)	Set lock state of button

Attributes:

`states`
`staticMetaObject`

states = ['DISABLED', 'UNLOCKED', 'LOCKED']
Possible states of Lock Button

load_pixmaps()
Load pixmaps used to display lock state to `Lock_Button.pixmaps`

set_state(*state*)
Set lock state of button

Should only be called by other objects (as there are checks to whether it's ok to start/stop that we shouldn't be aware of)

Parameters **state** (*str*) – `('OFF', 'ON', 'ALARM')`

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class `pvp.gui.widgets.control_panel.`**HeartBeat**(*update_interval: int = 100*, *timeout_dur: int = 5000*)
Track state of connection with Controller

Check when we last had contact with controller every `HeartBeat.update_interval` ms, if longer than `HeartBeat.timeout_dur` then emit a timeout signal

Parameters

- **update_interval** (*int*) – How often to do the heartbeat, in ms
- **timeout** (*int*) – how long to wait before hearing from control process, in ms

_state
whether the system is running or not

Type bool

_last_heartbeat
Timestamp of last contact with controller

Type float

start_time
Time that ventilation was started

Type float

timer
Timer that checks for last contact

Type `PySide2.QtCore.QTimer`

update_interval
How often to do the heartbeat, in ms

Type int

timeout
how long to wait before hearing from control process, in ms

Type int

Methods:

`_heartbeat`()	Called every (update_interval) milliseconds to set the check the status of the heartbeat.
`beatheart`(heartbeat_time)	Slot that receives timestamps of last contact with controller
`init_ui`()	Initialize labels and status indicator
`set_indicator`([state])	Set visual indicator
`set_state`(state)	Set running state
`start_timer`([update_interval])	Start *HeartBeat.timer* to check for contact with controller
`stop_timer`()	Stop timer and clear text

Attributes:

`heartbeat`(*args, **kwargs)
`staticMetaObject`
`timeout`(*args, **kwargs)

timeout (**args, **kwargs*) **= <PySide2.QtCore.Signal object>**
Signal that a timeout has occurred – too long between contact with controller.

heartbeat (**args, **kwargs*) **= <PySide2.QtCore.Signal object>**
Signal that requests to affirm contact with controller if no message has been received in timeout duration

init_ui ()
Initialize labels and status indicator

set_state (*state*)
Set running state

if just starting reset *HeartBeat._last_heartbeat*

Parameters **state** (*bool*) – Whether we are starting (True) or stopping (False)

set_indicator(*state=None*)
Set visual indicator

Parameters **state** (*'ALARM', 'OFF', 'NORMAL'*) – Current state of connection with controller

start_timer(*update_interval=None*)
Start `HeartBeat.timer` to check for contact with controller

Parameters **update_interval** (*int*) – How often (in ms) the timer should be updated. if None, use `self.update_interval`

stop_timer()
Stop timer and clear text

beatheart(*heartbeat_time*)
Slot that receives timestamps of last contact with controller

Parameters **heartbeat_time** (*float*) – timestamp of last contact with controller

_heartbeat()
Called every (update_interval) milliseconds to set the check the status of the heartbeat.

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.control_panel.**StopWatch**(*update_interval: float = 100*, **args*, ***kwargs*)
Simple widget to display ventilation time!

Parameters

- **update_interval** (*float*) – update clock every n seconds
- ***args** – passed to `PySide2.QtWidgets.QLabel`
- ****kwargs** – passed to `PySide2.QtWidgets.QLabel`

Methods:

`__init__`([update_interval])	Simple widget to display ventilation time!
`_update_time`()	
`init_ui`()	
`start_timer`([update_interval])	**param update_interval** How often (in ms) the timer should be updated.
`stop_timer`()	Stop timer and reset label

Attributes:

`staticMetaObject`	

__init__(*update_interval: float = 100*, **args*, ***kwargs*)
Simple widget to display ventilation time!

Parameters

- **update_interval** (*float*) – update clock every n seconds
- ***args** – passed to `PySide2.QtWidgets.QLabel`

- ****kwargs** – passed to `PySide2.QtWidgets.QLabel`

staticMetaObject = <PySide2.QtCore.QMetaObject object>

init_ui()

start_timer(*update_interval=None*)

Parameters **update_interval** (*float*) – How often (in ms) the timer should be updated.

stop_timer()

Stop timer and reset label

_update_time()

10.2.2 Alarm Bar

The *Alarm_Bar* displays *Alarm* status with *Alarm_Card* widgets and plays alarm sounds with the *Alarm_Sound_Player*

Classes:

`Alarm`(alarm_type, severity, start_time, . . .)	Representation of alarm status and parameters
`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
Alarm_Bar()	Holds and manages a collection of *Alarm_Card* s and communicates requests for dismissal to the *Alarm_Manager*
Alarm_Card(alarm)	Representation of an alarm raised by *Alarm_Manager* in GUI.
`Alarm_Manager`()	The Alarm Manager
Alarm_Sound_Player(increment_delay, *args, . . .)	Plays alarm sounds to reflect current alarm severity and active duration with `PySide2.QtMultimedia.QSoundEffect` objects

Functions:

`init_logger`(module_name[, log_level, . . .])	Initialize a logger for logging events.
`mono_font`()	module function to return a `PySide2.QtGui.QFont` to use as the mono font.

class pvp.gui.widgets.alarm_bar.**Alarm_Bar**

Holds and manages a collection of *Alarm_Card* s and communicates requests for dismissal to the *Alarm_Manager*

The alarm bar also manages the *Alarm_Sound_Player*

alarms

A list of active alarms

Type typing.List[*Alarm*]

alarm_cards

A list of active alarm cards

Type typing.List[*Alarm_Card*]

sound_player

Class that plays alarm sounds!

Type *Alarm_Sound_Player*

icons
Dictionary of pixmaps with icons for different alarm levels

Type dict

Methods:

add_alarm(alarm)	Add an alarm created by the *Alarm_Manager* to the bar.
clear_alarm([alarm, alarm_type])	Remove an alarm card, update appearance and sound player to reflect current max severity
init_ui()	Initialize the UI
make_icons()	Create pixmaps from standard icons to display for different alarm types
set_icon([state])	Change the icon and bar appearance to reflect the alarm severity
update_icon()	Call *set_icon()* with highest severity in *Alarm_Bar.alarms*

Attributes:

alarm_level	Current maximum *AlarmSeverity*
staticMetaObject	

make_icons()
Create pixmaps from standard icons to display for different alarm types

Store in *Alarm_Bar.icons*

init_ui()
Initialize the UI

- Create layout
- Set icon
- Create mute button

add_alarm(*alarm: pvp.alarm.alarm.Alarm*)
Add an alarm created by the *Alarm_Manager* to the bar.

If an alarm alreaady exists with that same *AlarmType*, *Alarm_Bar.clear_alarm()*

Insert new alarm in order the prioritizes alarm severity with highest severity on right

Set alarm sound and begin playing if not already.

Parameters **alarm** (*Alarm*) – Alarm to be added

clear_alarm(*alarm: pvp.alarm.alarm.Alarm = None*, *alarm_type: pvp.alarm.AlarmType = None*)
Remove an alarm card, update appearance and sound player to reflect current max severity

Must pass one of either `alarm` or `alarm_type`

Parameters

- **alarm** (*Alarm*) – Alarm to be cleared

- **alarm_type** (*AlarmType*) – Alarm type to be cleared

update_icon()

Call *set_icon()* with highest severity in *Alarm_Bar.alarms*

set_icon(*state: pvp.alarm.AlarmSeverity = None*)

Change the icon and bar appearance to reflect the alarm severity

Parameters **state** (*AlarmSeverity*) – Alarm Severity to display, if None change to default display

property alarm_level

Current maximum *AlarmSeverity*

Returns *AlarmSeverity*

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.alarm_bar.**Alarm_Card**(*alarm: pvp.alarm.alarm.Alarm*)

Representation of an alarm raised by *Alarm_Manager* in GUI.

If allowed by alarm (by `latch` setting) , allows user to dismiss/silence alarm.

Otherwise request to dismiss is logged by *Alarm_Manager* and the card is dismissed when the conditions that generated the alarm are no longer met.

Parameters **alarm** (*Alarm*) – Alarm to represent

alarm

The represented alarm

Type *Alarm*

severity

The severity of the represented alarm

Type *AlarmSeverity*

close_button

Button that requests an alarm be dismissed

Type `PySide2.QtWidgets.QPushButton`

Methods:

_dismiss()	Gets the *Alarm_Manager* instance and calls *Alarm_Manager.dismiss_alarm()*
init_ui()	Initialize graphical elements

Attributes:

staticMetaObject

init_ui()

Initialize graphical elements

- Create labels
- Set stylesheets
- Create and connect dismiss button

Returns:

_dismiss()

Gets the *Alarm_Manager* instance and calls *Alarm_Manager.dismiss_alarm()*

Also change appearance of close button to reflect requested dismissal

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.alarm_bar.**Alarm_Sound_Player**(*increment_delay: int = 10000*, **args*, ***kwargs*)

Plays alarm sounds to reflect current alarm severity and active duration with `PySide2.QtMultimedia.QSoundEffect` objects

Alarm sounds indicate severity with the number and pitch of tones in a repeating tone cluster (eg. low severity sounds have a single repeating tone, but high-severity alarms have three repeating tones)

They indicate active duration by incrementally removing a low-pass filter and making tones have a sharper attack and decay.

When an alarm of any severity is started the `<severity_0.wav` file begins playing, and a timer is started to call *Alarm_Sound_Player.increment_level()*

Parameters

- **increment_delay** (*int*) – Delay between calling *Alarm_Sound_Player.increment_level()*
- ****kwargs** (**args,*) – passed to `PySide2.QtWidgets.QWidget`

idx

Dictionary of dictionaries allowing sounds to be accessed like `self.idx[AlarmSeverity][level]`

Type dict

files

list of sound file paths

Type list

increment_delay

Time between calling `Alarm_Sound_Player.increment_level`()` in ms

Type int

playing

Whether or not a sound is playing

Type bool

_increment_timer

Timer that increments alarm sound level

Type `PySide2.QtCore.QTimer`

_changing_track

used to ensure single sound changing call happens at a time.

Type `threading.Lock`

Methods:

increment_level()	If current level is below the maximum level, increment with *Alarm_Sound_Player.set_sound()* Returns:
init_audio()	Load audio files in `pvp/external/audio` and add to *Alarm_Sound_Player.idx*
play()	Start sound playback
set_mute(mute)	Set mute state
set_sound([severity, level])	Set sound to be played
stop()	Stop sound playback

Attributes:

severity_map	mapping between string representations of severities used by filenames and *AlarmSeverity*
staticMetaObject	

severity_map = {'high': <AlarmSeverity.HIGH: 3>, 'low': <AlarmSeverity.LOW: 1>, 'med

mapping between string representations of severities used by filenames and *AlarmSeverity*

init_audio()

Load audio files in `pvp/external/audio` and add to *Alarm_Sound_Player.idx*

play()

Start sound playback

Play sound listed as `Alarm_Sound_Player._current_sound`

Note: *Alarm_Sound_Player.set_sound()* must be called first.

stop()

Stop sound playback

set_sound(*severity: pvp.alarm.AlarmSeverity = None*, *level: int = None*)

Set sound to be played

At least an *AlarmSeverity* must be provided.

Parameters

- **severity** (*AlarmSeverity*) – Severity of alarm sound to play
- **level** (*int*) – level (corresponding to active duration) of sound to play

increment_level()

If current level is below the maximum level, increment with *Alarm_Sound_Player.set_sound()* Returns:

staticMetaObject = <PySide2.QtCore.QMetaObject object>

set_mute(*mute: bool*)

Set mute state

Parameters **mute** (*bool*) – if True, mute. if False, unmute.

10.2.3 Display

Unified monitor & control widget

Displays sensor values, and can optionally control system settings.

The *PVP_Gui* instantiates display widgets according to the contents of *values.DISPLAY_CONTROL* and *values.DISPLAY_MONITOR*

Classes:

AlarmSeverity(value)	An enumeration.
ControlSetting(name, value, min_value, ...)	Message containing ventilation control parameters.
Display(value, update_period, enum_name, ...)	Unified widget for display of sensor values and control of ventilation parameters
DoubleSlider([decimals])	Slider capable of representing floats
EditableLabel([parent])	Editable label https://gist.github.com/mfessenden/baa2b87b8addb0b60e54a11c1da48046
Limits_Plot(style, *args, **kwargs)	Widget to display current value in a bar graph along with alarm limits
QVLine([parent, color])	
Value(name, units, abs_range, safe_range, ...)	Class to parameterize how a value is used in PVP.
ValueName(value)	Canonical names of all values used in PVP.

Functions:

init_logger(module_name[, log_level, ...])	Initialize a logger for logging events.
mono_font()	module function to return a PySide2.QtGui.QFont to use as the mono font.
pop_dialog(message[, sub_message, modality, ...])	Creates a dialog box to display a message.

class pvp.gui.widgets.display.**Display**(*value: pvp.common.values.Value, update_period: float = 0.5, enum_name: pvp.common.values.ValueName = None, button_orientation: str = 'left', control_type: Union[None, str] = None, style: str = 'dark', *args, **kwargs*)

Unified widget for display of sensor values and control of ventilation parameters

Displayed values are updated according to Dispaly.timed_update()

Parameters

- **value** (*Value*) – Value object to represent
- **update_period** (*float*) – Amount of time between updates of the textual display of values
- **enum_name** (*ValueName*) – Value name of object to represent
- **button_orientation** (*'left', 'right'*) – whether the controls are drawn on the 'left' or 'right'
- **control_type** (*None, 'slider', 'record'*) – type of control - either None (no control), slider (a slider can be opened to set a value), or record where recent sensor values are averaged and used to set the control value. Both types of control allow values to be input from the keyboard by clicking on the editable label

- **style** (*'light', 'dark'*) – whether the widget is `'dark'` (light text on dark background) or `'light'` (dark text on light background
- ****kwargs** (**args,*) – passed on to `PySide2.QtWidgets.QWidget`

`self.`**name**
Unpacked from `value`

`self.`**units**
Unpacked from `value`

`self.`**abs_range**
Unpacked from `value`

`self.`**safe_range**
Unpacked from `value`

`self.`**alarm_range**
initialized from `value`, but updated by alarm manager

`self.`**decimals**
Unpacked from `value`

`self.`**update_period**
Amount of time between updates of the textual display of values

Type float

`self.`**enum_name**
Value name of object to represent

Type *ValueName*

`self.`**orientation**
whether the controls are drawn on the `'left'` or `'right'`

Type 'left', 'right'

`self.`**control**
type of control - either `None` (no control), `slider` (a slider can be opened to set a value), or `record` where recent sensor values are averaged and used to set the control value.

Type None, 'slider', 'record'

`self.`**_style**
whether the widget is `'dark'` (light text on dark background) or `'light'` (dark text on light background)

Type 'light', 'dark'

`self.`**set_value**
current set value of controlled value, if any

Type float

`self.`**sensor_value**
current value of displayed sensor value, if any.

Type float

Methods:

_value_changed(new_value)	"outward-directed" method to emit new changed control value when changed by this widget
init_ui()	UI is initialized in several stages
init_ui_labels()	
init_ui_layout()	Basically two methods.
init_ui_limits()	Create widgets to display sensed value alongside set value
init_ui_record()	
init_ui_signals()	
init_ui_slider()	
init_ui_toggle_button()	
redraw()	Redraw all graphical elements to ensure internal model matches view
set_locked(locked)	Set locked status of control
set_units(units)	Set pressure units to display as cmH2O or hPa.
timed_update()	Refresh textual sensor values only periodically to prevent them from being totally unreadable from being changed too fast.
toggle_control(state)	Toggle the appearance of the slider, if a slider
toggle_record(state)	Toggle the recording state, if a recording control
update_limits(control)	Update the alarm range and the GUI elements corresponding to it
update_sensor_value(new_value)	Receive new sensor value and update display widgets
update_set_value(new_value)	Update to reflect new control value set from elsewhere (inwardly directed setter)

Attributes:

alarm_state	Current visual display of alarm severity
is_set	Check if value has been set for this control.
staticMetaObject	
value_changed(*args, **kwargs)	Signal emitted when controlled value of display object has changed.

value_changed(**args*, ***kwargs*) **= <PySide2.QtCore.Signal object>**

Signal emitted when controlled value of display object has changed.

Contains new value (float)

init_ui()

UI is initialized in several stages

- 0: this method, get stylesheets based on `self._style` and call remaining initialization methods
- 1: `Display.init_ui_labels()` - create generic labels shared by all display objects
- 2: `Display.init_ui_toggle_button()` - create the toggle or record button used by controls
- 3: `Display.init_ui_limits()` - create a plot that displays the sensor value graphically relative to the alarm limits
- 4: `Display.init_ui_slider()` or `Display.ini_ui_record()` - depending on what type of control this is
- 5: `Display.init_ui_layout()` since the results of the previous steps varies, do all layout at the end depending on orientation

- 6: `Display.init_ui_signals()` connect slots and signals

init_ui_labels()

init_ui_toggle_button()

init_ui_limits()
Create widgets to display sensed value alongside set value

init_ui_slider()

init_ui_record()

init_ui_layout()
Basically two methods... lay objects out depending on whether we're oriented with our button to the left or right

init_ui_signals()

toggle_control(*state*)
Toggle the appearance of the slider, if a slider

Parameters **state** (`bool`) – Whether to show or hide the slider

toggle_record(*state*)
Toggle the recording state, if a recording control

Parameters **state** (`bool`) – Whether recording should be started or stopped. when started, start storing new sensor values in a list. when stopped, average thgem and emit new value.

_value_changed(*new_value: float*)
"outward-directed" method to emit new changed control value when changed by this widget

Pop a confirmation dialog if values are set outside the safe range.

Parameters

- **new_value** (`float`) – new value!
- **emit** (`bool`) – whether to emit the *value_changed* signal (default True) – in the case that our value is being changed by someone other than us

update_set_value(*new_value: float*)
Update to reflect new control value set from elsewhere (inwardly directed setter)

Parameters **new_value** (`float`) – new value to set!

update_sensor_value(*new_value: float*)
Receive new sensor value and update display widgets

Parameters **new_value** (`float`) – new sensor value!

update_limits(*control:* pvp.common.message.ControlSetting)
Update the alarm range and the GUI elements corresponding to it

Parameters **control** (`ControlSetting`) – control setting with min_value or max_value

redraw()
Redraw all graphical elements to ensure internal model matches view

Typically used when changing units

timed_update()
Refresh textual sensor values only periodically to prevent them from being totally unreadable from being changed too fast.

set_units (*units: str*)

Set pressure units to display as cmH2O or hPa.

Uses functions from *pvp.common.unit_conversion* such that

- `self._convert_in` converts internal, canonical units to displayed units (eg. `cmH2O` is used by all other modules, so we convert it to `hPa`
- `self._convert_out` converts displayed units to send to other parts of the system

Note: currently unit conversion is only supported for Pressure.

Parameters **units** (*'cmH2O', 'hPa'*) – new units to display

set_locked (*locked: bool*)

Set locked status of control

Parameters **locked** (*bool*) – If True, disable all controlling widgets, if False, re-enable.

property is_set

Check if value has been set for this control.

Used to check if all settings have been set preflight by *PVP_Gui*

Returns whether we have an `Display.set_value`

Return type bool

property alarm_state

Current visual display of alarm severity

Change sensor value color to reflect the alarm state of that set parameter –

eg. if we have a HAPA alarm, set the PIP control to display as red.

Returns *AlarmSeverity*

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.display.**Limits_Plot** (*style: str = 'light', *args, **kwargs*)

Widget to display current value in a bar graph along with alarm limits

Parameters **style** (*'light', 'dark'*) – Whether we are being displayed in a light or dark styled *Display* widget

set_value

Set value of control, displayed as horizontal black line always set at center of bar

Type float

sensor_value

Sensor value to compare against control, displayed as bar

Type float

When initializing PlotWidget, *parent* and *background* are passed to `GraphicsWidget.__init__()` and all others are passed to `PlotItem.__init__()`.

Methods:

init_ui()	Create bar chart and horizontal lines to reflect

continues on next page

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update_value([min, max, sensor_value, set_value])	Move the lines! Pass any of the represented values.
update_yrange()	Set yrange to ensure that the set value is always in the center of the plot and that all the values are in range.

Attributes:

staticMetaObject

staticMetaObject = <PySide2.QtCore.QMetaObject object>

init_ui()

Create bar chart and horizontal lines to reflect

- Sensor Value
- Set Value
- High alarm limit
- Low alarm limit

update_value(*min: float = None*, *max: float = None*, *sensor_value: float = None*, *set_value: float = None*)

Move the lines! Pass any of the represented values.

Also updates yrange to ensure that the control value is always centered in the plot

Parameters

- **min** (*float*) – new alarm minimum
- **max** (*float*) – new alarm _maximum
- **sensor_value** (*float*) – new value for the sensor bar plot
- **set_value** (*float*) – new value for the set value line

update_yrange()

Set yrange to ensure that the set value is always in the center of the plot and that all the values are in range.

10.2.4 Plot

Widgets to plot waveforms of sensor values

The *PVP_Gui* creates a *Plot_Container* that allows the user to select

- which plots (of those in `values.PLOT`) are displayed
- the timescale (x range) of the displayed waveforms

Plots display alarm limits as red horizontal bars

Classes:

AlarmSeverity(value)	An enumeration.
ControlSetting(name, value, min_value, ...)	Message containing ventilation control parameters.
Plot(name[, buffer_size, plot_duration, ...])	Waveform plot of single sensor value.

continues on next page

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Plot_Container(plot_descriptors, . . .)	Container for multiple :class;`.Plot` objects
SensorValues([timestamp, loop_counter, . . .])	Structured class for communicating sensor readings throughout PVP.
Value(name, units, abs_range, safe_range, . . .)	Class to parameterize how a value is used in PVP.
ValueName(value)	Canonical names of all values used in PVP.
deque	deque([iterable[, maxlen]]) –> deque object

Data:

PLOT_FREQ	Update frequency of *Plot* s in Hz
PLOT_TIMER	A QTimer that updates :class:`.TimedPlotCurveItem`s

Functions:

get_gui_instance()	Retreive the currently running instance of the GUI
init_logger(module_name[, log_level, . . .])	Initialize a logger for logging events.
mono_font()	module function to return a PySide2.QtGui.QFont to use as the mono font.

pvp.gui.widgets.plot.**PLOT_TIMER = None**

A QTimer that updates :class:`.TimedPlotCurveItem`s

pvp.gui.widgets.plot.**PLOT_FREQ = 5**

Update frequency of *Plot* s in Hz

class pvp.gui.widgets.plot.**Plot**(*name*, *buffer_size=4092*, *plot_duration=10*, *plot_limits: tuple = None*, *color=None*, *units=''*, ***kwargs*)

Waveform plot of single sensor value.

Plots values continuously, wrapping at zero rather than shifting x axis.

Parameters

- **name** (*str*) – String version of *ValueName* used to set title
- **buffer_size** (*int*) – number of samples to store
- **plot_duration** (*float*) – default x-axis range
- **plot_limits** (*tuple*) – tuple of (ValueName)s for which to make pairs of min and max range lines
- **color** (*None, str*) – color of lines
- **units** (*str*) – Unit label to display along title
- ****kwargs** –

timestamps

deque of timestamps

Type collections.deque

history

deque of sensor values

Type collections.deque

cycles
deque of breath cycles

Type `collections.deque`

When initializing PlotWidget, *parent* and *background* are passed to `GraphicsWidget.__init__()` and all others are passed to `PlotItem.__init__()`.

Attributes:

limits_changed(*args, **kwargs)	
staticMetaObject	

Methods:

reset_start_time()	Reset start time – return the scrolling time bar to position 0
set_duration(dur)	Set duration, or span of x axis.
set_safe_limits(limits)	Set the position of the max and min lines for a given value
set_units(units)	Set displayed units
update_value(new_value)	Update with new sensor value

limits_changed(**args*, ***kwargs*) **= <PySide2.QtCore.Signal object>**

set_duration(*dur: float*)
Set duration, or span of x axis.

Parameters **dur** (*float*) – span of x axis (in seconds)

update_value(*new_value: tuple*)
Update with new sensor value

Parameters **new_value** (*tuple*) – (timestamp from time.time(), breath_cycle, value)

set_safe_limits(*limits: pvp.common.message.ControlSetting*)
Set the position of the max and min lines for a given value

Parameters **limits** (*ControlSetting*) – Controlsetting that has either a `min_value` or `max_value` defined

reset_start_time()
Reset start time – return the scrolling time bar to position 0

set_units(*units*)
Set displayed units

Currently only implemented for Pressure, display either in cmH2O or hPa

Parameters **units** (*'cmH2O', 'hPa'*) – unit to display pressure as

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.plot.**Plot_Container**(*plot_descriptors: Dict[pvp.common.values.ValueName, pvp.common.values.Value]*, **args*, ***kwargs*)
Container for multiple :class;`.Plot` objects

Allows user to show/hide different plots and adjust x-span (time zoom)

Note: Currently, the only unfortunately hardcoded parameter in the whole GUI is the instruction to initially hide FIO2, there should be an additional parameter in `Value` that says whether a plot should initialize as hidden or not

Todo: Currently, colors are set to alternate between orange and light blue on initialization, but they don't update when plots are shown/hidden, so the alternating can be lost and colors can look random depending on what's selcted.

Parameters **plot_descriptors** (*typing.Dict*[ValueName, Value]) – dict of *Value* items to plot

plots
Dict mapping *ValueName* s to *Plot* s

Type dict

slider
slider used to set x span

Type `PySide2.QtWidgets.QSlider`

Methods:

init_ui()	
reset_start_time()	Call *Plot.reset_start_time()* on all plots
set_duration(duration)	Set the current duration (span of the x axis) of all plots
set_plot_mode()	
set_safe_limits(control)	Try to set horizontal alarm limits on all relevant plots
toggle_plot(state)	Toggle the visibility of a plot.
update_value(vals)	Try to update all plots who have new sensorvalues

Attributes:

staticMetaObject

init_ui()

update_value(*vals: pvp.common.message.SensorValues*)
Try to update all plots who have new sensorvalues

Parameters **vals** (*SensorValues*) – Sensor Values to update plots with

toggle_plot(*state: bool*)
Toggle the visibility of a plot.

get the name of the plot from the `sender`'s `objectName`

Parameters **state** (*bool*) – Whether the plot should be visible (True) or not (False)

set_safe_limits(*control: pvp.common.message.ControlSetting*)
Try to set horizontal alarm limits on all relevant plots

Parameters **control** (*ControlSetting*) – with either `min_value` or `max_value` set

Returns:

set_duration(*duration: float*)
Set the current duration (span of the x axis) of all plots

Also make sure that the text box and slider reflect this duration

Parameters duration (*float*) – new duration to set

Returns:

reset_start_time()
Call *Plot.reset_start_time()* on all plots

staticMetaObject = <PySide2.QtCore.QMetaObject object>

set_plot_mode()

Todo: switch between longitudinal timeseries and overlaid by breath cycle!!!

10.2.5 Components

Very basic components used by other widgets.

These are relatively sparsely documented because their operation is mostly self-explanatory

Classes:

DoubleSlider([decimals])	Slider capable of representing floats
EditableLabel([parent])	Editable label https://gist.github.com/mfessenden/baa2b87b8addb0b60e54a11c1da48046
KeyPressHandler	Custom key press handler https://gist.github.com/mfessenden/baa2b87b8addb0b60e54a11c1da48046
OnOffButton(state_labels, str] =, toggled, …)	Simple extension of toggle button with styling for clearer 'ON' vs 'OFF'
QHLine([parent, color])	with respct to https://stackoverflow.com/a/51057516
QVLine([parent, color])	

Functions:

mono_font()	module function to return a PySide2.QtGui.QFont to use as the mono font.

class pvp.gui.widgets.components.**DoubleSlider**(*decimals=1*, **args*, ***kargs*)
Slider capable of representing floats

Ripped off from and https://stackoverflow.com/a/50300848 ,

Thank you!!!

Methods:

_maximum()
_minimum()

continues on next page

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_singleStep()	
emitDoubleValueChanged()	
maximum(self)	
minimum(self)	
setDecimals(decimals)	
setMaximum(self, arg__1)	
setMinimum(self, arg__1)	
setSingleStep(self, arg__1)	
setValue(self, arg__1)	
singleStep(self)	
value(self)	

Attributes:

doubleValueChanged(*args, **kwargs)	
staticMetaObject	

doubleValueChanged(**args, **kwargs*) = <PySide2.QtCore.Signal object>

setDecimals(*decimals*)

emitDoubleValueChanged()

value(*self*) → int

setMinimum(*self, arg__1: int*)

setMaximum(*self, arg__1: int*)

minimum(*self*) → int

_minimum()

maximum(*self*) → int

_maximum()

setSingleStep(*self, arg__1: int*)

singleStep(*self*) → int

_singleStep()

setValue(*self, arg__1: int*)

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.components.**KeyPressHandler**

Custom key press handler https://gist.github.com/mfessenden/baa2b87b8addb0b60e54a11c1da48046

Attributes:

escapePressed(*args, **kwargs)	
returnPressed(*args, **kwargs)	
staticMetaObject	

Methods:

eventFilter(self, watched, event)	

escapePressed(**args, **kwargs*) = <PySide2.QtCore.Signal object>

returnPressed(**args, **kwargs*) = <PySide2.QtCore.Signal object>

eventFilter(*self, watched: PySide2.QtCore.QObject, event: PySide2.QtCore.QEvent*) → bool

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.components.**EditableLabel**(*parent=None, **kwargs*)

Editable label https://gist.github.com/mfessenden/baa2b87b8addb0b60e54a11c1da48046

Methods:

create_signals()	
escapePressedAction()	Escape event handler
labelPressedEvent(event)	Set editable if the left mouse button is clicked
labelUpdatedAction()	Indicates the widget text has been updated
returnPressedAction()	Return/enter event handler
setEditable(editable)	
setLabelEditableAction()	Action to make the widget editable
setText(text)	Standard QLabel text setter
text()	Standard QLabel text getter

Attributes:

staticMetaObject	
textChanged(*args, **kwargs)	

textChanged(**args, **kwargs*) = <PySide2.QtCore.Signal object>

create_signals()

text()

Standard QLabel text getter

setText(*text*)

Standard QLabel text setter

labelPressedEvent(*event*)

Set editable if the left mouse button is clicked

setLabelEditableAction()

Action to make the widget editable

setEditable(*editable: bool*)

labelUpdatedAction()

Indicates the widget text has been updated

returnPressedAction()

Return/enter event handler

escapePressedAction()

Escape event handler

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.components.**QHLine**(*parent=None*, *color='#FFFFFF'*)
with respct to https://stackoverflow.com/a/51057516

Methods:

setColor(color)	

Attributes:

staticMetaObject	

setColor(*color*)

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.components.**QVLine**(*parent=None*, *color='#FFFFFF'*)

Methods:

setColor(color)	

Attributes:

staticMetaObject	

setColor(*color*)

staticMetaObject = <PySide2.QtCore.QMetaObject object>

class pvp.gui.widgets.components.**OnOffButton**(*state_labels: Tuple[str, str] = 'ON', 'OFF'*, *toggled: bool = False*, **args*, ***kwargs*)
Simple extension of toggle button with styling for clearer 'ON' vs 'OFF'

Parameters

- **state_labels** (*tuple*) – tuple of strings to set when toggled and untoggled
- **toggled** (*bool*) – initialize the button as toggled
- ***args** – passed to QPushButton
- ****kwargs** – passed to QPushButton

Methods:

__init__([state_labels, toggled])	**param state_labels** tuple of strings to set when toggled and untoggled
set_state(state)	

Attributes:

staticMetaObject	

__init__(*state_labels: Tuple[str, str] = 'ON', 'OFF'*, *toggled: bool = False*, **args*, ***kwargs*)

Parameters

- **state_labels** (*tuple*) – tuple of strings to set when toggled and untoggled
- **toggled** (*bool*) – initialize the button as toggled
- ***args** – passed to `QPushButton`
- ****kwargs** – passed to `QPushButton`

set_state (*state: bool*)

staticMetaObject = <PySide2.QtCore.QMetaObject object>

10.2.6 Dialog

Function to display a dialog to the user and receive feedback!

Functions:

`get_gui_instance`()	Retreive the currently running instance of the GUI
`init_logger`(module_name[, log_level, . . .])	Initialize a logger for logging events.
pop_dialog(message[, sub_message, modality, . . .])	Creates a dialog box to display a message.

`pvp.gui.widgets.dialog.`**pop_dialog** (*message: str, sub_message: str = None, modality: <class 'PySide2.QtCore.Qt.WindowModality'> = PySide2.QtCore.Qt.WindowModality.NonModal, buttons: <class 'PySide2.QtWidgets.QMessageBox.StandardButton'> = PySide2.QtWidgets.QMessageBox.StandardButton.Ok, default_button: <class 'PySide2.QtWidgets.QMessageBox.StandardButton'> = PySide2.QtWidgets.QMessageBox.StandardButton.Ok*)

Creates a dialog box to display a message.

Note: This function does *not* call *.exec_* on the dialog so that it can be managed by the caller.

Parameters

- **message** (*str*) – Message to be displayed
- **sub_message** (*str*) – Smaller message displayed below main message (InformativeText)
- **modality** (*QtCore.Qt.WindowModality*) – Modality of dialog box - QtCore.Qt.NonModal (default) is unblocking, QtCore.Qt.WindowModal is blocking
- **buttons** (*QtWidgets.QMessageBox.StandardButton*) – Buttons for the window, can be `|` ed together
- **default_button** (*QtWidgets.QMessageBox.StandardButton*) – one of `buttons`, the highlighted button

Returns QtWidgets.QMessageBox

10.3 GUI Stylesheets

Classes:

AlarmSeverity(value)	An enumeration.

Data:

MONITOR_UPDATE_INTERVAL	inter-update interval (seconds) for Monitor

Functions:

set_dark_palette(app)	Apply Dark Theme to the Qt application instance.

pvp.gui.styles.**MONITOR_UPDATE_INTERVAL = 0.5**
inter-update interval (seconds) for Monitor

Type (float)

pvp.gui.styles.**set_dark_palette**(*app*)
Apply Dark Theme to the Qt application instance.

borrowed from https://github.com/gmarull/qtmodern/blob/master/qtmodern/styles.py

Args: app (QApplication): QApplication instance.

The GUI is written using PySide2 and consists of one main *PVP_Gui* object that instantiates a series of *GUI Widgets*. The GUI is responsible for setting ventilation control parameters and sending them to the controller (see *set_control()*), as well as receiving and displaying sensor values (*get_sensors()*).

The GUI also feeds the *Alarm_Manager* *SensorValues* objects so that it can compute alarm state. The *Alarm_Manager* reciprocally updates the GUI with *Alarm* s (*PVP_Gui.handle_alarm()*) and Alarm limits (*PVP_Gui.limits_updated()*).

The main **polling loop** of the GUI is *PVP_Gui.update_gui()* which queries the controller for new *SensorValues* and distributes them to all listening widgets (see method documentation for more details). The rest of the GUI is event driven, usually with Qt Signals and Slots.

The GUI is **configured** by the *values* module, in particular it creates

- *Display* widgets in the left "sensor monitor" box from all *Value* s in *DISPLAY_MONITOR* ,
- *Display* widgets in the right "control" box from all *Value* s in *DISPLAY_CONTROL* , and
- *Plot* widgets in the center plot box from all *Value* s in PLOT

The GUI is not intended to be launched alone, as it needs an active coordinator to communicate with the controller process and a few prelaunch preparations (*launch_gui()*). PVP should be started like:

```
python3 -m pvp.main
```

10.4 Module Overview

10.5 Screenshot

images/gui_overview_v1_1920px.png

CHAPTER

ELEVEN

CONTROLLER

11.1 Screenshot

images/single_waveform.png

The Controller consists of one main `controller` object that receives sensor-data, and computes control parameters, to change valve settings. The controller receives ventilation control parameters (see *set_control()*), and can provide the currently active set of controls (see???)

The Controller also feeds the `Logger` *SensorValues* objects so that it can store high-temporal resolution data.

The main **polling loop** of the Controller is *PVP_Gui.update_gui()* which queries the Hardware for new variables, that are wired up in a new *SensorValues* and distributes them to all listening widgets (see method documentation for more details).

The Controller is **configured** by the *values* module, in particular it creates

- *Display* widgets in the left "sensor monitor" box from all *Value* s in *DISPLAY_MONITOR* ,

The Controller can be launched alone:

but was not intended to be launched alone.

add logging

Classes:

`Alarm`(alarm_type, severity, start_time, ...)	Representation of alarm status and parameters
`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
Balloon_Simulator(peep_valve)	Physics simulator for inflating a balloon with an attached PEEP valve.
ControlModuleBase(save_logs, flush_every)	Abstract controller class for simulation/hardware.
ControlModuleDevice([save_logs, ...])	Uses ControlModuleBase to control the hardware.
ControlModuleSimulator([simulator_dt, ...])	Controlling Simulation.
`ControlSetting`(name, value, min_value, ...)	Message containing ventilation control parameters.
`ControlValues`(control_signal_in, ...)	Class to save control values, analogous to SensorValues.
`DataLogger`(compression_level)	Class for logging numerical respiration data and control settings. Creates a hdf5 file with this general structure: / root |— waveforms (group) | |— time | pressure_data | flow_out | control_signal_in | control_signal_out | FiO2 | Cycle No. | |— controls (group) | |— (time, controllsignal) | |— derived_quantities (group) | |— (time, Cycle No, I_PHASE_DURATION, PIP_TIME, PEEP_time, PIP, PIP_PLATEAU, PEEP, VTE) | |.
`DerivedValues`(timestamp, breath_count, ...)	Class to save derived values, analogous to SensorValues.
`SensorValues`([timestamp, loop_counter, ...])	Structured class for communicating sensor readings throughout PVP.
`ValueName`(value)	Canonical names of all values used in PVP.
`count`	count(start=0, step=1) –> count object
`deque`	deque([iterable[, maxlen]]) –> deque object

Data:

`List`	The central part of internal API.

Functions:

get_control_module([sim_mode, simulator_dt])	Generates control module.

continues on next page

Table 3 – continued from previous page

`init_logger`(module_name[, log_level, . . .])	Initialize a logger for logging events.
`timeout`(func)	Defines a decorator for a 50ms timeout.

class pvp.controller.control_module.**ControlModuleBase**(*save_logs: bool = False, flush_every: int = 10*)

Bases: `object`

Abstract controller class for simulation/hardware.

1. General notes: All internal variables fall in three classes, denoted by the beginning of the variable:
   - *COPY_varname*: These are copies (for safe threading purposes) that are regularly sync'ed with internal variables.
   - *__varname*: These are variables only used in the ControlModuleBase-Class
   - *_varname*: These are variables used in derived classes.
2. Set and get values. Internal variables should only to be accessed though the **set_** and **get_** functions.

   These functions act on COPIES of internal variables (__ and _), that are sync'd every few iterations. How often this is done is adjusted by the variable *self._NUMBER_CONTROLL_LOOPS_UNTIL_UPDATE*. To avoid multiple threads manipulating the same variables at the same time, every manipulation of *COPY_* is surrounded by a thread lock.

Public Methods:

- *get_sensors()*: Returns a copy of the current sensor values.
- *get_alarms()*: Returns a List of all alarms, active and logged
- *get_control(ControlSetting)*: Sets a controll-setting. Is updated at latest within self._NUMBER_CONTROLL_LOOPS_UNTIL_UPDATE
- *get_past_waveforms()*: Returns a List of waveforms of pressure and volume during at the last N breath cycles, N<self. _RINGBUFFER_SIZE, AND clears this archive.
- *start()*: Starts the main-loop of the controller
- *stop()*: Stops the main-loop of the controller
- *set_control()*: Set the control
- *interrupt()*: Interrupt the controller, and re-spawns the thread. Used to restart a stuck controller
- *is_running()*: Returns a bool whether the main-thread is running
- *get_heartbeat()*: Returns a heartbeat, more specifically, the continuously increasing iteration-number of the main control loop.

Initializes the ControlModuleBase class.

Parameters

- **save_logs** (`bool`, `optional`) – Should sensor data and controls should be saved with the `DataLogger`? Defaults to False.
- **flush_every** (`int`, `optional`) – Flush and rotate logs every n breath cycles. Defaults to 10.

Raises **alert** – [description]

Methods:

`_PID_update`(dt)	This instantiates the PID control algorithms. During the breathing cycle, it goes through the four states: 1) Rise to PIP, speed is controlled by flow (variable: *__SET_PIP_GAIN*) 2) Sustain PIP pressure 3) Quick fall to PEEP 4) Sustaint PEEP pressure Once the cycle is complete, it checks the cycle for any alarms, and starts a new one. A record of pressure/volume waveforms is kept and saved.
`__init__`([save_logs, flush_every])	Initializes the ControlModuleBase class.
`_control_reset`()	Resets the internal controller cycle to zero, i.e. restarts the breath cycle.
`_controls_from_COPY`()	
`_get_control_signal_in`()	Produces the INSPIRATORY control-signal that has been calculated in *__calculate_control_signal_in(dt)*
`_get_control_signal_out`()	Produces the EXPIRATORY control-signal for the different states, i.e. open/close.
`_initialize_set_to_COPY`()	Makes a copy of internal variables.
`_sensor_to_COPY`()	
`_start_mainloop`()	Prototype method to start main PID loop.
`get_alarms`()	A method callable from the outside to get a copy of the alarms, that the controller checks: High airway pressure, and technical alarms.
`get_control`(control_setting_name)	A method callable from the outside to get current control settings.
`get_heartbeat`()	Returns an independent heart-beat of the controller, i.e. the internal loop counter incremented in *_start_mainloop*.
`get_past_waveforms`()	Public method to return a list of past waveforms from *__cycle_waveform_archive*. Note: After calling this function, archive is emptied! The format is - Returns a list of [Nx3] waveforms, of [time, pressure, volume] - Most recent entry is waveform_list[-1].
`get_sensors`()	A method callable from the outside to get a copy of sensorValues
`interrupt`()	If the controller seems stuck, this generates a new thread, and starts the main loop.
`is_running`()	Public Method to assess whether the main loop thread is running.
`set_breath_detection`(breath_detection)	
`set_control`(control_setting)	A method callable from the outside to set alarms.
`start`()	Method to start *_start_mainloop* as a thread.
`stop`()	Method to stop the main loop thread, and close the logfile.

`__init__`(*save_logs: bool = False*, *flush_every: int = 10*)

Initializes the ControlModuleBase class.

Parameters

- **save_logs** (`bool`, `optional`) – Should sensor data and controls should be saved with the `DataLogger`? Defaults to False.

- **flush_every** (*int, optional*) – Flush and rotate logs every n breath cycles. Defaults to 10.

Raises **alert** – [description]

_initialize_set_to_COPY()
Makes a copy of internal variables. This is used to facilitate threading

_sensor_to_COPY()

_controls_from_COPY()

__analyze_last_waveform()

This goes through the last waveform, and updates the internal variables: VTE, PEEP, PIP, PIP_TIME, I_PHASE, FIRST_PEEP and BPM.

get_sensors() → *pvp.common.message.SensorValues*
A method callable from the outside to get a copy of sensorValues

Returns A set of current sensorvalues, handeled by the controller.

Return type *SensorValues*

get_alarms() → Union[None, Tuple[*pvp.alarm.alarm.Alarm*]]
A method callable from the outside to get a copy of the alarms, that the controller checks: High airway pressure, and technical alarms.

Returns A tuple of alarms

Return type typing.Union[None, typing.Tuple[*Alarm*]]

set_control(*control_setting:* pvp.common.message.ControlSetting)
A method callable from the outside to set alarms. This updates the entries of COPY with new control values.

Parameters **control_setting** (ControlSetting) – [description]

get_control(*control_setting_name:* pvp.common.values.ValueName) → *pvp.common.message.ControlSetting*
A method callable from the outside to get current control settings. This returns values of COPY to the outside world.

Parameters **control_setting_name** (ValueName) – The specific control asked for

Returns ControlSettings-Object that contains relevant data

Return type *ControlSetting*

set_breath_detection(*breath_detection:* bool)

__get_PID_error(*ytarget, yis, dt, RC*)
Calculates the three terms for PID control. Also takes a timestep "dt" on which the integral-term is smoothed.

Parameters

- **ytarget** (*float*) – target value of pressure
- **yis** (*float*) – current value of pressure
- **dt** (*float*) – timestep
- **RC** (*float*) – time constant for calculation of integral term.

__calculate_control_signal_in(*dt*)

Calculates the PID control signal by:

- Combining the the three gain parameters.
- And smoothing the control signal with a moving window of three frames (~10ms)

Parameters `dt` (*float*) – timestep

`_get_control_signal_in()`

Produces the INSPIRATORY control-signal that has been calculated in *__calculate_control_signal_in(dt)*

Returns the numerical control signal for the inspiratory prop valve

Return type float

`_get_control_signal_out()`

Produces the EXPIRATORY control-signal for the different states, i.e. open/close

Returns numerical control signal for expiratory side: open (1) close (0)

Return type float

`_control_reset()`

Resets the internal controller cycle to zero, i.e. restarts the breath cycle. Used for autonomous breath detection.

`__test_for_alarms()`

Implements tests that are to be executed in the main control loop:

- Test for HAPA
- Test for Technical Alert, making sure sensor values are plausible
- Test for Technical Alert, make sure continuous in contact

Currently: Alarms are time.time() of first occurance.

`__start_new_breathcycle()`

Some housekeeping. This has to be executed when the next breath cycles starts:

- starts new breathcycle
- initializes newe __cycle_waveform
- analyzes last breath waveform for PIP, PEEP etc. with *__analyze_last_waveform()*
- flushes the logfile

`_PID_update(dt)`

This instantiates the PID control algorithms. During the breathing cycle, it goes through the four states:

1) Rise to PIP, speed is controlled by flow (variable: *__SET_PIP_GAIN*)
2) Sustain PIP pressure
3) Quick fall to PEEP
4) Sustaint PEEP pressure

Once the cycle is complete, it checks the cycle for any alarms, and starts a new one. A record of pressure/volume waveforms is kept and saved

Parameters `dt` (*float*) – timesstep since last update

`__save_values()`

Helper function to reorganize key parameters in the main PID control loop, into a *SensorValues* object, that can be stored in the logfile, using a method from the DataLogger.

get_past_waveforms()
Public method to return a list of past waveforms from *__cycle_waveform_archive*. Note: After calling this function, archive is emptied! The format is

- Returns a list of [Nx3] waveforms, of [time, pressure, volume]
- Most recent entry is waveform_list[-1]

Returns [Nx3] waveforms, of [time, pressure, volume]

Return type list

_start_mainloop()
Prototype method to start main PID loop. Will depend on simulation or device, specified below.

start()
Method to start *_start_mainloop* as a thread.

stop()
Method to stop the main loop thread, and close the logfile.

interrupt()
If the controller seems stuck, this generates a new thread, and starts the main loop. No parameters have changed.

is_running()
Public Method to assess whether the main loop thread is running.

Returns Return true if and only if the main thread of controller is running.

Return type bool

get_heartbeat()
Returns an independent heart-beat of the controller, i.e. the internal loop counter incremented in *_start_mainloop*.

Returns exact value of *self._loop_counter*

Return type int

class pvp.controller.control_module.**ControlModuleDevice**(*save_logs=True*, *flush_every=10*, *config_file=None*)
Bases: *pvp.controller.control_module.ControlModuleBase*

Uses ControlModuleBase to control the hardware.

Initializes the ControlModule for the physical system. Inherits methods from ControlModuleBase

Parameters

- **save_logs** (*bool, optional*) – Should logs be kept? Defaults to True.
- **flush_every** (*int, optional*) – How often are log-files to be flushed, in units of main-loop-itertions? Defaults to 10.
- **config_file** (*str, optional*) – Path to device config file, e.g. ‘pvp/io/config/dinky-devices.ini’. Defaults to None.

Methods:

`__init__`([save_logs, flush_every, config_file])	Initializes the ControlModule for the physical system.
`_get_HAL`()	Get sensor values from HAL, decorated with timeout.
`_sensor_to_COPY`()	Copies the current measurements to`COPY_sensor_values`, so that it can be queried from the outside.
`_set_HAL`(valve_open_in, valve_open_out)	Set Controls with HAL, decorated with a timeout.
`_start_mainloop`()	This is the main loop.
`set_valves_standby`()	This returns valves back to normal setting (in: closed, out: open)

`__init__`(*save_logs=True*, *flush_every=10*, *config_file=None*)
Initializes the ControlModule for the physical system. Inherits methods from ControlModuleBase

Parameters

- **save_logs** (*bool, optional*) – Should logs be kept? Defaults to True.
- **flush_every** (*int, optional*) – How often are log-files to be flushed, in units of main-loop-itertions? Defaults to 10.
- **config_file** (*str, optional*) – Path to device config file, e.g. 'pvp/io/config/dinky-devices.ini'. Defaults to None.

`_sensor_to_COPY`()
Copies the current measurements to`COPY_sensor_values`, so that it can be queried from the outside.

`_set_HAL`(*valve_open_in*, *valve_open_out*)
Set Controls with HAL, decorated with a timeout.

As hardware communication is the speed bottleneck. this code is slightly optimized in so far as only changes are sent to hardware.

Parameters

- **valve_open_in** (*float*) – setting of the inspiratory valve; should be in range [0,100]
- **valve_open_out** (*float*) – setting of the expiratory valve; should be 1/0 (open and close)

`_get_HAL`()
Get sensor values from HAL, decorated with timeout. As hardware communication is the speed bottleneck. this code is slightly optimized in so far as some sensors are queried only in certain phases of the breatch cycle. This is done to run the primary PID loop as fast as possible:

- pressure is always queried
- Flow is queried only outside of inspiration
- In addition, oxygen is only read every 5 seconds.

`set_valves_standby`()
This returns valves back to normal setting (in: closed, out: open)

`_start_mainloop`()
This is the main loop. This method should be run as a thread (see the *start()* method in *ControlModuleBase*)

class `pvp.controller.control_module.`**`Balloon_Simulator`**(*peep_valve*)
Bases: `object`

Physics simulator for inflating a balloon with an attached PEEP valve. For math, see https://en.wikipedia.org/wiki/Two-balloon_experiment

Methods:

OUupdate(variable, dt, mu, sigma, tau)	This is a simple function to produce an OU process on *variable*.
_reset()	Resets Balloon to default settings.
get_pressure()	
get_volume()	
set_flow_in(Qin, dt)	
set_flow_out(Qout, dt)	
update(dt)	

get_pressure()

get_volume()

set_flow_in(*Qin*, *dt*)

set_flow_out(*Qout*, *dt*)

update(*dt*)

OUupdate(*variable*, *dt*, *mu*, *sigma*, *tau*)

This is a simple function to produce an OU process on *variable*. It is used as model for fluctuations in measurement variables.

Parameters

- **variable** (*float*) – value of a variable at previous time step
- **dt** (*float*) – timestep
- **mu** (*float)*) – mean
- **sigma** (*float*) – noise amplitude
- **tau** (*float*) – time scale

Returns value of "variable" at next time step

Return type float

_reset()

Resets Balloon to default settings.

class pvp.controller.control_module.**ControlModuleSimulator**(*simulator_dt=None*, *peep_valve_setting=5*)

Bases: *pvp.controller.control_module.ControlModuleBase*

Controlling Simulation.

Initializes the ControlModuleBase with the simple simulation (for testing/dev).

Parameters

- **simulator_dt** (*float, optional*) – timestep between updates. Defaults to None.
- **peep_valve_setting** (*int, optional*) – Simulates action of a PEEP valve. Pressure cannot fall below. Defaults to 5.

Methods:

`__init__`([simulator_dt, peep_valve_setting])	Initializes the ControlModuleBase with the simple simulation (for testing/dev).
`_sensor_to_COPY`()	Make the sensor value object from current (simulated) measurements
`_start_mainloop`()	This is the main loop.

`__init__`(*simulator_dt=None*, *peep_valve_setting=5*)
Initializes the ControlModuleBase with the simple simulation (for testing/dev).

Parameters

- **simulator_dt** (*float, optional*) – timestep between updates. Defaults to None.
- **peep_valve_setting** (*int, optional*) – Simulates action of a PEEP valve. Pressure cannot fall below. Defaults to 5.

`__SimulatedPropValve`(*x*)
This simulates the action of a proportional valve. Flow-current-curve eye-balled from generic prop vale with logistic activation.

Parameters **x** (*float*) – A control variable [like pulse-width-duty cycle or mA]

Returns flow through the valve

Return type float

`__SimulatedSolenoid`(*x*)
This simulates the action of a two-state Solenoid valve.

Parameters **x** (*float*) – If x==0: valve closed; x>0: flow set to "1"

Returns current flow

Return type float

`_sensor_to_COPY`()
Make the sensor value object from current (simulated) measurements

`_start_mainloop`()
This is the main loop. This method should be run as a thread (see the *start()* method in *ControlModuleBase*)

`pvp.controller.control_module.`**`get_control_module`**(*sim_mode=False*, *simulator_dt=None*)
Generates control module.

Parameters

- **sim_mode** (*bool, optional*) – if `true`: returns simulation, else returns hardware. Defaults to False.
- **simulator_dt** (*float, optional*) – a timescale for thee simulation. Defaults to None.

Returns Either configured for simulation, or physical device.

Return type ControlModule-Object

Control into a breathing cycle was accomplished with ahybrid system of state and PID control. During inspiration,we actively control pressure using a PID cycle to set theinspiratory valve. Expiration was then instantiated by closingthe inpiratory, and opening the expiratory valve to passivelyrelease PIP pressure as fast as possible. After reaching PEEP,we opened the inspiratory valve slightly to sustain PEEPusing the aforementioned manually operated PEEP-valveand to sustain a gentle flow of air through the system

The Raspberry pi allowed for the primary control loop torun at speeds exceeding320Hz, using40%of themaximum bandwidth of the analog-to-digital converterreading the sensors

In addition to pressure control, our software continuouslymonitors for autonomous breaths, high airway pressure,and general system status.Autonomous breathing wasdetected by transient pressure drops below PEEP. A detectedbreath triggered a new breath cycle. High airway pressureis defined as exceeding a certain pressure for a certain time(as to not be triggered by a cough). This triggered an alarm,and an immediate release of air to drop pressure to PEEP.The Controller also assesses whether numerical values arereasonable, and changing over time. If this is not the case,it raises an technical alarm. All alarms are collected andmaintained by an intelligent alarm manager, that provides theUI with the alarms to display in order of their importance.In addition to the alarm system, the controller monitorsfor autonomous breath events during peep. We define suchevents by a drop below the PEEP baseline exceeding somefixed threshold. If an autonomous drop was detected, thenext breath cycle is initiated

CHAPTER

TWELVE

COMMON MODULE

12.1 Values

Parameterization of variables and values used in PVP.

Value objects define the existence and behavior of values, including creating *Display* and *Plot* widgets in the GUI, and the contents of *SensorValues* and *ControlSetting* s used between the GUI and controller.

Data:

CONTROL	Values to control but not monitor.
DISPLAY_CONTROL	Control values that should also have a widget created in the GUI
DISPLAY_MONITOR	Those sensor values that should also have a widget created in the GUI
PLOTS	Values that can be plotted
SENSOR	Sensor values
VALUES	Declaration of all values used by PVP

Classes:

Enum(value)	Generic enumeration.
Value(name, units, abs_range, safe_range, ...)	Class to parameterize how a value is used in PVP.
ValueName(value)	Canonical names of all values used in PVP.
auto()	Instances are replaced with an appropriate value in Enum class suites.
odict	alias of collections.OrderedDict

class pvp.common.values.**ValueName**(*value*)

Bases: enum.Enum

Canonical names of all values used in PVP.

Attributes:

PIP
PIP_TIME
PEEP
PEEP_TIME
BREATHS_PER_MINUTE

continues on next page

Table 3 – continued from previous page

INSPIRATION_TIME_SEC
IE_RATIO
FIO2
VTE
PRESSURE
FLOWOUT

PIP = 1

PIP_TIME = 2

PEEP = 3

PEEP_TIME = 4

BREATHS_PER_MINUTE = 5

INSPIRATION_TIME_SEC = 6

IE_RATIO = 7

FIO2 = 8

VTE = 9

PRESSURE = 10

FLOWOUT = 11

class pvp.common.values.**Value**(*name: str, units: str, abs_range: tuple, safe_range: tuple, decimals: int, control: bool, sensor: bool, display: bool, plot: bool = False, plot_limits: Union[None, Tuple[pvp.common.values.ValueName]] = None, control_type: Union[None, str] = None, group: Union[None, dict] = None, default: (<class 'int'>, <class 'float'>) = None*)

Bases: object

Class to parameterize how a value is used in PVP.

Sets whether a value is a sensor value, a control value, whether it should be plotted, and other details for the rest of the system to determine how to use it.

Values should only be declared in this file so that they are kept consistent with *ValueName* and to not leak stray values anywhere else in the program.

Parameters

- **name** (*str*) – Human-readable name of the value
- **units** (*str*) – Human-readable description of units
- **abs_range** (*tuple*) – tuple of ints or floats setting the logical limit of the value, eg. a percent between 0 and 100, (0, 100)
- **safe_range** (*tuple*) – tuple of ints or floats setting the safe ranges of the value,

  note:

  ```
  this is not the same thing as the user-set alarm values,
  though the user-set alarm values are initialized as ``safe_range``.
  ```

- **decimals** (*int*) – the number of decimals of precision used when displaying the value
- **control** (*bool*) – Whether or not the value is used to control ventilation

- **sensor** (*bool*) – Whether or not the value is a measured sensor value
- **display** (*bool*) – whether the value should be created as a `gui.widgets.Display` widget.
- **plot** (*bool*) – whether or not the value is plottable in the center plot window
- **plot_limits** (*None, tuple(ValueName)*) – If plottable, and the plotted value has some alarm limits for another value, plot those limits as horizontal lines in the plot. eg. the PIP alarm range limits should be plotted on the Pressure plot
- **control_type** (*None, "slider", "record"*) – If a control sets whether the control should use a slider or be set by recording recent sensor values.
- **group** (*None, str*) – Unused currently, but to be used to create subgroups of control & display widgets
- **default** (*None, int, float*) – Default value, if any. (Not automatically set in the GUI.)

Methods:

__init__(name, units, abs_range, safe_range, . . .)	**param name** Human-readable name of the value
to_dict()	Gather up all attributes and return as a dict!

Attributes:

abs_range	tuple of ints or floats setting the logical limit of the value, eg.
control	Whether or not the value is used to control ventilation
control_type	If a control sets whether the control should use a slider or be set by recording recent sensor values.
decimals	The number of decimals of precision used when displaying the value
default	Default value, if any.
display	Whether the value should be created as a `gui.widgets.Display` widget.
group	Unused currently, but to be used to create subgroups of control & display widgets
name	Human readable name of value
plot	whether or not the value is plottable in the center plot window
plot_limits	If plottable, and the plotted value has some alarm limits for another value, plot those limits as horizontal lines in the plot.
safe_range	tuple of ints or floats setting the safe ranges of the value,
sensor	Whether or not the value is a measured sensor value

__init__(*name: str*, *units: str*, *abs_range: tuple*, *safe_range: tuple*, *decimals: int*, *control: bool*, *sensor: bool*, *display: bool*, *plot: bool = False*, *plot_limits: Union[None, Tuple[pvp.common.values.ValueName]] = None*, *control_type: Union[None, str] = None*, *group: Union[None, dict] = None*, *default: (<class 'int'>, <class 'float'>) = None*)

Parameters

- **name** (*str*) – Human-readable name of the value
- **units** (*str*) – Human-readable description of units
- **abs_range** (*tuple*) – tuple of ints or floats setting the logical limit of the value, eg. a percent between 0 and 100, (0, 100)
- **safe_range** (*tuple*) – tuple of ints or floats setting the safe ranges of the value,

  note:

  ```
  this is not the same thing as the user-set alarm values,
  though the user-set alarm values are initialized as ``safe_
  ↪range``.
  ```

- **decimals** (*int*) – the number of decimals of precision used when displaying the value
- **control** (*bool*) – Whether or not the value is used to control ventilation
- **sensor** (*bool*) – Whether or not the value is a measured sensor value
- **display** (*bool*) – whether the value should be created as a `gui.widgets.Display` widget.
- **plot** (*bool*) – whether or not the value is plottable in the center plot window
- **plot_limits** (*None, tuple(ValueName)*) – If plottable, and the plotted value has some alarm limits for another value, plot those limits as horizontal lines in the plot. eg. the PIP alarm range limits should be plotted on the Pressure plot
- **control_type** (*None, "slider", "record"*) – If a control sets whether the control should use a slider or be set by recording recent sensor values.
- **group** (*None, str*) – Unused currently, but to be used to create subgroups of control & display widgets
- **default** (*None, int, float*) – Default value, if any. (Not automatically set in the GUI.)

property name

Human readable name of value

Returns str

property abs_range

tuple of ints or floats setting the logical limit of the value, eg. a percent between 0 and 100, (0, 100)

Returns tuple

property safe_range

tuple of ints or floats setting the safe ranges of the value,

note:

```
this is not the same thing as the user-set alarm values,
though the user-set alarm values are initialized as ``safe_range``.
```

Returns tuple

property decimals
The number of decimals of precision used when displaying the value

Returns int

property default
Default value, if any. (Not automatically set in the GUI.)

property control
Whether or not the value is used to control ventilation

Returns bool

property sensor
Whether or not the value is a measured sensor value

Returns bool

property display
Whether the value should be created as a `gui.widgets.Display` widget.

Returns bool

property control_type
If a control sets whether the control should use a slider or be set by recording recent sensor values.

Returns None, "slider", "record"

property group
Unused currently, but to be used to create subgroups of control & display widgets

Returns None, str

property plot
whether or not the value is plottable in the center plot window

Returns bool

property plot_limits
If plottable, and the plotted value has some alarm limits for another value, plot those limits as horizontal lines in the plot. eg. the PIP alarm range limits should be plotted on the Pressure plot

Returns None, typing.Tuple[ValueName]

to_dict() → dict
Gather up all attributes and return as a dict!

Returns dict

pvp.common.values.**VALUES = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Value obje**
Declaration of all values used by PVP

pvp.common.values.**SENSOR = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Value obje**
Sensor values

Automatically generated as all *Value* objects in *VALUES* where `sensor == True`

pvp.common.values.**CONTROL = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Value obje**
Values to control but not monitor.

Automatically generated as all *Value* objects in *VALUES* where `control == True`

pvp.common.values.**DISPLAY_MONITOR = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Va**
Those sensor values that should also have a widget created in the GUI

Automatically generated as all *Value* objects in *VALUES* where `sensor == True` and `display == True`

pvp.common.values.**DISPLAY_CONTROL = OrderedDict([(<ValueName.PIP: 1>, <pvp.common.values.Va**
Control values that should also have a widget created in the GUI

Automatically generated as all *Value* objects in *VALUES* where `control == True` and `display == True`

pvp.common.values.**PLOTS = OrderedDict([(<ValueName.PRESSURE: 10>, <pvp.common.values.Value**
Values that can be plotted

Automatically generated as all *Value* objects in *VALUES* where `plot == True`

12.2 Message

Message objects that define the API between modules in the system.

- *SensorValues* are used to communicate sensor readings between the controller, GUI, and alarm manager
- *ControlSetting* is used to set ventilation controls from the GUI to the controller.

Classes:

ControlSetting(name, value, min_value, . . .)	Message containing ventilation control parameters.
ControlValues(control_signal_in, . . .)	Class to save control values, analogous to SensorValues.
DerivedValues(timestamp, breath_count, . . .)	Class to save derived values, analogous to SensorValues.
SensorValues([timestamp, loop_counter, . . .])	Structured class for communicating sensor readings throughout PVP.
odict	alias of `collections.OrderedDict`

Functions:

copy(x)	Shallow copy operation on arbitrary Python objects.
init_logger(module_name[, log_level, . . .])	Initialize a logger for logging events.

class pvp.common.message.**SensorValues**(*timestamp=None, loop_counter=None, breath_count=None, vals=typing.Union[NoneType, typing.Dict[ForwardRef('ValueName'), float]], **kwargs*)

Bases: `object`

Structured class for communicating sensor readings throughout PVP.

Should be instantiated with each of the *SensorValues.additional_values*, and values for all *ValueName* s in *values.SENSOR* by passing them in the `vals` kwarg. An `AssertionError` if an incomplete set of values is given.

Values can be accessed either via attribute name (`SensorValues.PIP`) or like a dictionary (`SensorValues['PIP']`)

Parameters

- **timestamp** (*float*) – from time.time(). must be passed explicitly or as an entry in `vals`

- **loop_counter** (*int*) – number of control_module loops. must be passed explicitly or as an entry in `vals`
- **breath_count** (*int*) – number of breaths taken. must be passed explicitly or as an entry in `vals`
- **vals** (*None, dict*) – Dict of `{ValueName: float}` that contains current sensor readings. Can also be equivalently given as `kwargs` . if None, assumed values are being passed as kwargs, but an exception will be raised if they aren't.
- ****kwargs** – sensor readings, must be in `pvp.values.SENSOR.keys`

Methods:

`__init__`([timestamp, loop_counter, ...])	**param timestamp** from time.time(). must be passed explicitly or as an entry in `vals`
`to_dict`()	Return a dictionary of all sensor values and additional values

Attributes:

`additional_values`	Additional attributes that are not `ValueName` s that are expected in each SensorValues message

additional_values = ('timestamp', 'loop_counter', 'breath_count')
Additional attributes that are not `ValueName` s that are expected in each SensorValues message

__init__(*timestamp=None, loop_counter=None, breath_count=None, vals=typing.Union[NoneType, typing.Dict[ForwardRef('ValueName'), float]], **kwargs*)

Parameters

- **timestamp** (*float*) – from time.time(). must be passed explicitly or as an entry in `vals`
- **loop_counter** (*int*) – number of control_module loops. must be passed explicitly or as an entry in `vals`
- **breath_count** (*int*) – number of breaths taken. must be passed explicitly or as an entry in `vals`
- **vals** (*None, dict*) – Dict of `{ValueName: float}` that contains current sensor readings. Can also be equivalently given as `kwargs` . if None, assumed values are being passed as kwargs, but an exception will be raised if they aren't.
- ****kwargs** – sensor readings, must be in `pvp.values.SENSOR.keys`

to_dict() → dict
Return a dictionary of all sensor values and additional values

Returns dict

class pvp.common.message.**ControlSetting**(*name: pvp.common.values.ValueName, value: float = None, min_value: float = None, max_value: float = None, timestamp: float = None, range_severity: AlarmSeverity = None*)

Bases: `object`

Message containing ventilation control parameters.

At least **one of** `value`, `min_value`, or `max_value` must be given (unlike `SensorValues` which requires all fields to be present) – eg. in the case where one is setting alarm thresholds without changing the actual set value

When a parameter has multiple alarm limits for different alarm severities, the severity should be passed to `range_severity`

Parameters

- **name** (*ValueName*) – Name of value being set
- **value** (*float*) – Value to set control
- **min_value** (*float*) – Value to set control minimum (typically used for alarm thresholds)
- **max_value** (*float*) – Value to set control maximum (typically used for alarm thresholds)
- **timestamp** (*float*) – `time.time()` control message was generated
- **range_severity** (*AlarmSeverity*) – Some control settings have multiple limits for different alarm severities, this attr, when present, specifies which is being set.

Methods:

`__init__`(name[, value, min_value, . . .])	Message containing ventilation control parameters.

__init__(*name: pvp.common.values.ValueName*, *value: float = None*, *min_value: float = None*, *max_value: float = None*, *timestamp: float = None*, *range_severity: AlarmSeverity = None*)

Message containing ventilation control parameters.

At least **one of** `value`, `min_value`, or `max_value` must be given (unlike `SensorValues` which requires all fields to be present) – eg. in the case where one is setting alarm thresholds without changing the actual set value

When a parameter has multiple alarm limits for different alarm severities, the severity should be passed to `range_severity`

Parameters

- **name** (*ValueName*) – Name of value being set
- **value** (*float*) – Value to set control
- **min_value** (*float*) – Value to set control minimum (typically used for alarm thresholds)
- **max_value** (*float*) – Value to set control maximum (typically used for alarm thresholds)
- **timestamp** (*float*) – `time.time()` control message was generated
- **range_severity** (*AlarmSeverity*) – Some control settings have multiple limits for different alarm severities, this attr, when present, specifies which is being set.

class `pvp.common.message.`**ControlValues**(*control_signal_in*, *control_signal_out*)

Bases: `object`

Class to save control values, analogous to SensorValues.

Used by the controller to save waveform data in `DataLogger.store_waveform_data()` and `ControlModuleBase.__save_values`()`

Key difference: SensorValues come exclusively from the sensors, ControlValues contains controller variables, i.e. control signals and controlled signals (the flows). :param control_signal_in: :param control_signal_out:

class pvp.common.message.**DerivedValues**(*timestamp*, *breath_count*, *I_phase_duration*, *pip_time*, *peep_time*, *pip*, *pip_plateau*, *peep*, *vte*)

Bases: object

Class to save derived values, analogous to SensorValues.

Used by controller to store derived values (like PIP from Pressure) in *DataLogger.store_derived_data()* and in ControlModuleBase.__analyze_last_waveform`()

Key difference: SensorValues come exclusively from the sensors, DerivedValues contain estimates of I_PHASE_DURATION, PIP_TIME, PEEP_time, PIP, PIP_PLATEAU, PEEP, and VTE. :param timestamp: :param breath_count: :param I_phase_duration: :param pip_time: :param peep_time: :param pip: :param pip_plateau: :param peep: :param vte:

12.3 Loggers

Logging functionality

There are two types of loggers:

- *loggers.init_logger()* creates a standard logging.Logger -based logging system for debugging and recording system events, and a
- *loggers.DataLogger* - a tables - based class to store continuously measured sensor values.

Classes:

ContinuousData()	Structure for the hdf5-table for continuous waveform data; measured once per controller loop.
ControlCommand()	Structure for the hdf5-table to store control commands.
CycleData()	Structure for the hdf5-table to store derived quantities from waveform measurements.
DataLogger(compression_level)	Class for logging numerical respiration data and control settings. Creates a hdf5 file with this general structure: / root |— waveforms (group) | |— time | pressure_data | flow_out | control_signal_in | control_signal_out | FiO2 | Cycle No. | |— controls (group) | |— (time, controllsignal) | |— derived_quantities (group) | |— (time, Cycle No, I_PHASE_DURATION, PIP_TIME, PEEP_time, PIP, PIP_PLATEAU, PEEP, VTE) | |.
datetime(year, month, day[, hour[, minute[, . . .)	The year, month and day arguments are required.

Data:

_LOGGERS	list of strings, which loggers have been created already.

Functions:

init_logger(module_name[, log_level, . . .])	Initialize a logger for logging events.

continues on next page

Table 13 – continued from previous page

update_logger_sizes()	Adjust each logger's `maxBytes` attribute so that the total across all loggers is `prefs.LOGGING_MAX_BYTES`

`pvp.common.loggers._LOGGERS = ['pvp.common.prefs', 'pvp.alarm.alarm_manager']`
list of strings, which loggers have been created already.

`pvp.common.loggers.init_logger` (*module_name: str*, *log_level: int = None*, *file_handler: bool = True*) → logging.Logger
Initialize a logger for logging events.

To keep logs sensible, you should usually initialize the logger with the name of the module that's using it, eg:

```
logger = init_logger(__name__)
```

If a logger has already been initialized (ie. its name is in *loggers._LOGGERS*, return that.

otherwise configure and return the logger such that

- its `LOGLEVEL` is set to `prefs.LOGLEVEL`
- It formats logging messages with logger name, time, and logging level
- if a file handler is specified (default), create a `logging.RotatingFileHandler` according to params set in `prefs`

Parameters

- **module_name** (*str*) – module name used to generate filename and name logger
- **log_level** (*int*) – one of **:var:`logging.DEBUG`**, **:var:`logging.INFO`**, **:var:`logging.WARNING`**, or **:var:`logging.ERROR`**
- **file_handler** (*bool*, *str*) – if `True`, (default), log in `<logdir>/module_name.log` . if `False`, don't log to disk.

Returns Logger 4 u 2 use

Return type `logging.Logger`

`pvp.common.loggers.update_logger_sizes()`
Adjust each logger's `maxBytes` attribute so that the total across all loggers is `prefs.LOGGING_MAX_BYTES`

class `pvp.common.loggers.DataLogger` (*compression_level: int = 9*)
Bases: `object`

Class for logging numerical respiration data and control settings. Creates a hdf5 file with this general structure:

/ root |— waveforms (group) | |— time | pressure_data | flow_out | control_signal_in | control_signal_out | FiO2 | Cycle No. | |— controls (group) | |— (time, controllsignal) | |— derived_quantities (group) | |— (time, Cycle No, I_PHASE_DURATION, PIP_TIME, PEEP_time, PIP, PIP_PLATEAU, PEEP, VTE) | |

Public Methods: close_logfile(): Flushes, and closes the logfile. store_waveform_data(SensorValues): Takes data from SensorValues, but DOES NOT FLUSH store_controls(): Store controls in the same file? TODO: Discuss flush_logfile(): Flush the data into the file

Initialized the coontinuous numerical logger class.

Parameters **compression_level** (*int*, *optional*) – Compression level of the hdf5 file. Defaults to 9.

Methods:

__init__([compression_level])	Initialized the coontinuous numerical logger class.
_open_logfile()	Opens the hdf5 file and generates the file structure.
check_files()	make sure that the file's are not getting too large.
close_logfile()	Flushes & closes the open hdf file.
flush_logfile()	This flushes the datapoints to the file.
load_file([filename])	This loads a hdf5 file, and returns data to the user as a dictionary with two keys: waveform_data and control_data
log2csv([filename])	Translates the compressed hdf5 into three csv files containing:
log2mat([filename])	Translates the compressed hdf5 into a matlab file containing a matlab struct. This struct has the same structure as the hdf5 file, but is not compressed. Use for any file: dl = DataLogger() dl.log2mat(filename) The file is saved at the same path as *.mat* file, where the content is represented as matlab-structs.
rotation_newfile()	This rotates through filenames, similar to a ring-buffer, to make sure that the program does not run of of space/
store_control_command(control_setting)	Appends a datapoint to the event-table, derived from ControlSettings
store_derived_data(derived_values)	Appends a datapoint to the event-table, derived the continuous data (PIP, PEEP etc.)
store_waveform_data(sensor_values, …)	Appends a datapoint to the file for continuous logging of streaming data.

__init__(*compression_level: int = 9*)

Initialized the coontinuous numerical logger class.

Parameters **compression_level** (*int*, *optional*) – Compression level of the hdf5 file. Defaults to 9.

_open_logfile()

Opens the hdf5 file and generates the file structure.

close_logfile()

Flushes & closes the open hdf file.

store_waveform_data(*sensor_values: SensorValues*, *control_values: ControlValues*)

Appends a datapoint to the file for continuous logging of streaming data. NOTE: Not flushed yet.

Parameters

- **sensor_values** (*SensorValues*) – SensorValues to be stored in the file.
- **control_values** (*ControlValues*) – ControlValues to be stored in the file

store_control_command(*control_setting: ControlSetting*)

Appends a datapoint to the event-table, derived from ControlSettings

Parameters **control_setting** (*ControlSetting*) – ControlSettings object, the content of which should be stored

store_derived_data (*derived_values: DerivedValues*)
Appends a datapoint to the event-table, derived the continuous data (PIP, PEEP etc.)

Parameters **derived_values** (DerivedValues) – DerivedValues object, the content of which should be stored

flush_logfile ()
This flushes the datapoints to the file. To be executed every other second, e.g. at the end of breath cycle.

check_files ()
make sure that the file's are not getting too large.

rotation_newfile ()
This rotates through filenames, similar to a ringbuffer, to make sure that the program does not run of of space/

load_file (*filename=None*)
This loads a hdf5 file, and returns data to the user as a dictionary with two keys: waveform_data and control_data

Parameters **filename** (*str, optional*) – Path to a hdf5-file. If none is given, uses currently open file. Defaults to None.

Returns Containing the data arranged as ` {"waveform_data": waveform_data, "control_data": control_data, "derived_data": derived_data}`

Return type dictionary

log2mat (*filename=None*)
Translates the compressed hdf5 into a matlab file containing a matlab struct. This struct has the same structure as the hdf5 file, but is not compressed. Use for any file:

dl = DataLogger() dl.log2mat(filename)

The file is saved at the same path as *.mat* file, where the content is represented as matlab-structs.

Parameters **filename** (*str, optional*) – Path to a hdf5-file. If none is given, uses currently open file. Defaults to None.

log2csv (*filename=None*)

Translates the compressed hdf5 into three csv files containing:

- waveform_data (measurement once per cycle)
- derived_quantities (PEEP, PIP etc.)
- control_commands (control commands sent to the controller)

This approximates the structure contained in the hdf5 file. Use for any file:

dl = DataLogger() dl.log2csv(filename)

Parameters **filename** (*str, optional*) – Path to a hdf5-file. If none is given, uses currently open file. Defaults to None.

12.4 Prefs

Prefs set configurable parameters used throughout PVP.

See *prefs._DEFAULTS* for description of all available parameters

Prefs are stored in a .json file, by default located at `~/pvp/prefs.json`. Prefs can be manually changed by editing this file (when the system is not running, when the system is running use *prefs.set_pref()*).

When any module in pvp is first imported, the *prefs.init()* function is called that

- Makes any directories listed in *prefs._DIRECTORIES*
- Declares all prefs as their default values from *prefs._DEFAULTS* to ensure they are always defined
- Loads the existing `prefs.json` file and updates values from their defaults

Prefs can be gotten and set from anywhere in the system with *prefs.get_pref()* and *prefs.set_pref()* . Prefs are stored in a `multiprocessing.Manager` dictionary which makes these methods both thread- and process-safe. Whenever a pref is set, the `prefs.json` file is updated to reflect the new value, so preferences are durable between runtimes.

Additional `prefs` should be added by adding an entry in the *prefs._DEFAULTS* dict rather than hardcoding them elsewhere in the program.

Data:

LOADED	flag to indicate whether prefs have been loaded (and thus *set_pref()* should write to disk).
_DEFAULTS	Declare all available parameters and set default values.
_DIRECTORIES	Directories to ensure are created and added to prefs.
_LOCK	Locks access to *prefs_fn*
_LOGGER	A `logging.Logger` to log pref init and setting events
_PREFS	The dict created by *prefs._PREF_MANAGER* to store prefs.
_PREF_MANAGER	The `multiprocessing.Manager` that stores prefs during system operation

Classes:

`c_bool`	

Functions:

get_pref([key])	Get global configuration value
init()	Initialize prefs.
load_prefs(prefs_fn)	Load prefs from a .json prefs file, combining (and over-writing) any existing prefs, and then saves.
make_dirs()	ensures _DIRECTORIES are created and added to prefs.
save_prefs([prefs_fn])	Dumps loaded prefs to `PREFS_FN`.
set_pref(key, val)	Sets a pref in the manager and, if *prefs.LOADED* is True, calls *prefs.save_prefs()*

`pvp.common.prefs.`**`_PREF_MANAGER = <multiprocessing.managers.SyncManager object>`**

The `multiprocessing.Manager` that stores prefs during system operation

`pvp.common.prefs.`**`_PREFS = <DictProxy object, typeid 'dict'>`**
The dict created by *`prefs._PREF_MANAGER`* to store prefs.

`pvp.common.prefs.`**`_LOGGER = <Logger pvp.common.prefs (WARNING)>`**
A `logging.Logger` to log pref init and setting events

`pvp.common.prefs.`**`_LOCK = <Lock(owner=None)>`**
Locks access to *prefs_fn*

Type `mp.Lock`

`pvp.common.prefs.`**`_DIRECTORIES = {'DATA_DIR': '/home/docs/pvp/logs', 'LOG_DIR': '/home/docs/`**
Directories to ensure are created and added to prefs.

- `VENT_DIR`: ~/pvp - base directory for user storage
- `LOG_DIR`: ~/pvp/logs - for storage of event and alarm logs
- `DATA_DIR`: ~/pvp/data - for storage of waveform data

`pvp.common.prefs.`**`LOADED = <Synchronized wrapper for c_bool(True)>`**
flag to indicate whether prefs have been loaded (and thus *`set_pref()`* should write to disk).

uses a `multiprocessing.Value` to be thread and process safe.

Type bool

`pvp.common.prefs.`**`_DEFAULTS = {'BREATH_DETECTION': True, 'BREATH_PRESSURE_DROP': 4, 'CONTROL`**
Declare all available parameters and set default values. If no default, set as None.

- `PREFS_FN` - absolute path to the prefs file
- `TIME_FIRST_START` - time when the program has been started for the first time
- `VENT_DIR`: ~/pvp - base directory for user storage
- `LOG_DIR`: ~/pvp/logs - for storage of event and alarm logs
- `DATA_DIR`: ~/pvp/data - for storage of waveform data
- `LOGGING_MAX_BYTES` : the **total** storage space for all loggers – each logger gets `LOGGING_MAX_BYTES/len(loggers)` space (2GB by default)
- `LOGGING_MAX_FILES` : number of files to split each logger's logs across (default: 5)
- `LOGLEVEL`: One of `('DEBUG', 'INFO', 'WARNING', 'EXCEPTION')` that sets the minimum log level that is printed and written to disk
- `TIMEOUT`: timeout used for timeout decorators on time-sensitive operations (in seconds, default 0.05)
- `HEARTBEAT_TIMEOUT`: Time between heartbeats between GUI and controller after which contact is assumed to be lost (in seconds, default 0.02)
- `GUI_STATE_FN`: Filename of gui control state file, relative to `VENT_DIR` (default: gui_state.json)
- `GUI_UPDATE_TIME`: Time between calls of *`PVP_Gui.update_gui()`* (in seconds, default: 0.05)
- `ENABLE_DIALOGS`: Enable all GUI dialogs – set as False when testing on virtual frame buffer that doesn't support them (default: True and should stay that way)
- `ENABLE_WARNINGS`: Enable user warnings and value change confirmations (default: True)
- `CONTROLLER_MAX_FLOW`: Maximum flow, above which the controller considers a sensor error (default: 10)

- `CONTROLLER_MAX_PRESSURE`: Maximum pressure, above which the controller considers a sensor error (default: 100)
- `CONTROLLER_MAX_STUCK_SENSOR`: Max amount of time (in s) before considering a sensor stuck (default: 0.2)
- `CONTROLLER_LOOP_UPDATE_TIME`: Amount of time to sleep in between controller update times when using *ControlModuleDevice* (default: 0.0)
- `CONTROLLER_LOOP_UPDATE_TIME_SIMULATOR`: Amount of time to sleep in between controller updates when using *ControlModuleSimulator* (default: 0.005)
- `CONTROLLER_LOOPS_UNTIL_UPDATE`: Number of controller loops in between updating its externally-available `COPY` attributes retrieved by `ControlModuleBase.get_sensor()` et al
- `CONTROLLER_RINGBUFFER_SIZE`: Maximum number of breath cycle records to be kept in memory (default: 100)
- `COUGH_DURATION`: Amount of time the high-pressure alarm limit can be exceeded and considered a cough (in seconds, default: 0.1)
- `BREATH_PRESSURE_DROP`: Amount pressure can drop below set PEEP before being considered an autonomous breath when in breath detection mode
- `BREATH_DETECTION`: Whether the controller should detect autonomous breaths in order to reset ventilation cycles (default: True)

`pvp.common.prefs.`**`set_pref`**`(`*key: str*, *val*`)`

Sets a pref in the manager and, if *prefs.LOADED* is True, calls *prefs.save_prefs()*

Parameters

- **key** (*str*) – Name of pref key
- **val** – Value to set

`pvp.common.prefs.`**`get_pref`**`(`*key: str = None*`)`

Get global configuration value

Parameters **key** (*str, None*) – get configuration value with specific `key` . if `None` , return all config values.

`pvp.common.prefs.`**`load_prefs`**`(`*prefs_fn: str*`)`

Load prefs from a .json prefs file, combining (and overwriting) any existing prefs, and then saves.

Called on pvp import by *prefs.init()*

Also initializes *prefs._LOGGER*

Note: once this function is called, *set_pref()* will update the prefs file on disk. So if *load_prefs()* is called again at any point it should not change prefs.

Parameters **prefs_fn** (*str*) – path of prefs.json

`pvp.common.prefs.`**`save_prefs`**`(`*prefs_fn: str = None*`)`

Dumps loaded prefs to `PREFS_FN`.

Parameters **prefs_fn** (*str*) – Location to dump prefs. if None, use existing `PREFS_FN`

`pvp.common.prefs.`**`make_dirs`**`()`

ensures _DIRECTORIES are created and added to prefs.

pvp.common.prefs.**init**()

Initialize prefs. Called in pvp.__init__.py to ensure prefs are initialized before anything else.

12.5 Unit Conversion

Functions that convert between units

Each function should accept a single float as an argument and return a single float

Used by the GUI to display values in different units. Widgets use these as

- _convert_in functions to convert units from the base unit to the displayed unit and
- _convert_out functions to convert units from the displayed unit to the base unit.

Note: Unit conversions are cosmetic – values are always kept as the base unit internally (ie. cmH2O for pressure) and all that is changed is the displayed value in the GUI.

Functions:

cmH2O_to_hPa(pressure)	Convert cmH2O to hPa
hPa_to_cmH2O(pressure)	Convert hPa to cmH2O
rounded_string(value[, decimals])	Create a rounded string of a number that doesnt have trailing .0 when decimals = 0

pvp.common.unit_conversion.**cmH2O_to_hPa**(*pressure: float*) → float

Convert cmH2O to hPa

Parameters **pressure** (*float*) – Pressure in cmH2O

Returns Pressure in hPa (pressure*98.0665)

Return type float

pvp.common.unit_conversion.**hPa_to_cmH2O**(*pressure: float*) → float

Convert hPa to cmH2O

Parameters **pressure** (*float*) – Pressure in hPa

Returns Pressure in cmH2O (pressure/98.0665)

Return type float

pvp.common.unit_conversion.**rounded_string**(*value: float, decimals: int = 0*) → str

Create a rounded string of a number that doesnt have trailing .0 when decimals = 0

Parameters

- **value** (*float*) – Value to stringify
- **decimals** (*int*) – Number of decimal places to round to

Returns Clean rounded string version of number

Return type str

12.6 utils

Exceptions:

TimeoutException

Functions:

`contextmanager`(func)	@contextmanager decorator.
`init_logger`(module_name[, log_level, ...])	Initialize a logger for logging events.
time_limit(seconds)	
timeout(func)	Defines a decorator for a 50ms timeout.

exception `pvp.common.utils.`**`TimeoutException`**
Bases: `Exception`

`pvp.common.utils.`**`time_limit`**(*seconds*)

`pvp.common.utils.`**`timeout`**(*func*)
Defines a decorator for a 50ms timeout. Usage/Test:

@timeout def foo(sleeptime):

time.sleep(sleeptime)

print("hello")

12.7 fashion

Decorators for dangerous functions

Functions:

`init_logger`(module_name[, log_level, ...])	Initialize a logger for logging events.
locked(func)	Wrapper to use as decorator, handle lock logic for a @property
pigpio_command(func)	

`pvp.common.fashion.`**`locked`**(*func*)
Wrapper to use as decorator, handle lock logic for a @property

Parameters **func** (*callable*) – function to wrap

`pvp.common.fashion.`**`pigpio_command`**(*func*)

CHAPTER

THIRTEEN

PVP.IO PACKAGE

13.1 Subpackages

13.2 Submodules

13.3 pvp.io.hal module

Module for interacting with physical and/or simulated devices installed on the ventilator.

Classes:

Hal([config_file])	Hardware Abstraction Layer for ventilator hardware.
Sensor()	Abstract base Class describing generalized sensors.

Functions:

import_module(name[, package])	Import a module.
literal_eval(node_or_string)	Safely evaluate an expression node or a string containing a Python expression.

class pvp.io.hal.**Hal**(*config_file='pvp/io/config/devices.ini'*)

Bases: object

Hardware Abstraction Layer for ventilator hardware. Defines a common API for interacting with the sensors & actuators on the ventilator. The types of devices installed on the ventilator (real or simulated) are specified in a configuration file.

Initializes HAL from config_file. For each section in config_file, imports the class <type> from module <module>, and sets attribute self.<section> = <type>(**opts), where opts is a dict containing all of the options in <section> that are not <type> or <section>. For example, upon encountering the following entry in config_file.ini:

[adc] type = ADS1115 module = devices i2c_address = 0x48 i2c_bus = 1

The Hal will:

1) **Import pvp.io.devices.ADS1115 (or ADS1015) as a local variable: class_** = getattr(import_module('.devices', 'pvp.io'), 'ADS1115')

2) **Instantiate an ADS1115 object with the arguments defined in config_file and set it as an attribute:** self._adc = class_(pig=self.-pig,address=0x48,i2c_bus=1)

Note: RawConfigParser.optionxform() is overloaded here s.t. options are case sensitive (they are by default case insensitive). This is necessary due to the kwarg MUX which is so named for consistency with the config registry documentation in the ADS1115 datasheet. For example, A P4vMini pressure_sensor on pin A0 (MUX=0) of the ADC is passed arguments like:

analog_sensor = AnalogSensor(pig=self._pig, adc=self._adc, MUX=0, offset_voltage=0.25, output_span = 4.0, conversion_factor=2.54*20

)

Note: ast.literal_eval(opt) interprets integers, 0xFF, (a, b) etc. correctly. It does not interpret strings correctly, nor does it know 'adc' -> self._adc; therefore, these special cases are explicitly handled.

Parameters **config_file** (*str*) – Path to the configuration file containing the definitions of specific components on the ventilator machine. (e.g., config_file = "pvp/io/config/devices.ini")

Methods:

`__init__`([config_file])	Initializes HAL from config_file.

Attributes:

`aux_pressure`	Returns the pressure from the auxiliary pressure sensor, if so equipped.
`flow_ex`	The measured flow rate expiratory side.
`flow_in`	The measured flow rate inspiratory side.
`oxygen`	Returns the oxygen concentration from the primary oxygen sensor.
`pressure`	Returns the pressure from the primary pressure sensor.
`setpoint_ex`	The currently requested flow on the expiratory side as a proportion of the maximum.
`setpoint_in`	The currently requested flow for the inspiratory proportional control valve as a proportion of maximum.

__init__(*config_file='pvp/io/config/devices.ini'*)

Initializes HAL from config_file. For each section in config_file, imports the class <type> from module <module>, and sets attribute self.<section> = <type>(**opts), where opts is a dict containing all of the options in <section> that are not <type> or <section>. For example, upon encountering the following entry in config_file.ini:

[adc] type = ADS1115 module = devices i2c_address = 0x48 i2c_bus = 1

The Hal will:

1) **Import pvp.io.devices.ADS1115 (or ADS1015) as a local variable:** class_ = getattr(import_module('.devices', 'pvp.io'), 'ADS1115')

2) **Instantiate an ADS1115 object with the arguments defined in config_file and set it as an attribute:** self._adc = class_(pig=self.-pig,address=0x48,i2c_bus=1)

Note: RawConfigParser.optionxform() is overloaded here s.t. options are case sensitive (they are by default case insensitive). This is necessary due to the kwarg MUX which is so named for consistency with the config registry documentation in the ADS1115 datasheet. For example, A P4vMini pressure_sensor on pin A0 (MUX=0) of the ADC is passed arguments like:

analog_sensor = AnalogSensor(pig=self._pig, adc=self._adc, MUX=0, offset_voltage=0.25, output_span = 4.0, conversion_factor=2.54*20

)

Note: ast.literal_eval(opt) interprets integers, 0xFF, (a, b) etc. correctly. It does not interpret strings correctly, nor does it know 'adc' -> self._adc; therefore, these special cases are explicitly handled.

Parameters **config_file** (*str*) – Path to the configuration file containing the definitions of specific components on the ventilator machine. (e.g., config_file = "pvp/io/config/devices.ini")

property pressure
Returns the pressure from the primary pressure sensor.

property oxygen
Returns the oxygen concentration from the primary oxygen sensor.

property aux_pressure
Returns the pressure from the auxiliary pressure sensor, if so equipped. If a secondary pressure sensor is not defined, raises a RuntimeWarning.

property flow_in
The measured flow rate inspiratory side.

property flow_ex
The measured flow rate expiratory side.

property setpoint_in
The currently requested flow for the inspiratory proportional control valve as a proportion of maximum.

property setpoint_ex
The currently requested flow on the expiratory side as a proportion of the maximum.

13.4 Module contents

Classes:

Hal([config_file])	Hardware Abstraction Layer for ventilator hardware.

CHAPTER

FOURTEEN

ALARM

14.1 Alarm System Overview

- Alarms are represented as `Alarm` objects, which are created and managed by the `Alarm_Manager`.
- A collection of `Alarm_Rule` s define the `Condition` s for raising `Alarm` s of different `AlarmSeverity` .
- The alarm manager is continuously fed `SensorValues` objects during `PVP_Gui.update_gui()`, which it uses to `check()` each alarm rule.
- The alarm manager emits `Alarm` objects to the `PVP_Gui.handle_alarm()` method.
- The alarm manager also updates alarm thresholds set as `Condition.depends` to `PVP_Gui.limits_updated()` when control parameters are set (eg. updates the `HIGH_PRESSURE` alarm to be triggered 15% above some set `PIP`).

14.2 Alarm Modules

14.2.1 Alarm Manager

The alarm manager is responsible for checking the `Alarm_Rule` s and maintaining the `Alarm` s active in the system.

Only one instance of the `Alarm_Manager` can be created at once, and if it is instantiated again, the existing object will be returned.

Classes:

`Alarm`(alarm_type, severity, start_time, ...)	Representation of alarm status and parameters
`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
`Alarm_Manager`()	The Alarm Manager
`Alarm_Rule`(name, conditions[, latch, technical])	• name of rule
`Condition`(depends, *args, **kwargs)	Base class for specifying alarm test conditions
`ControlSetting`(name, value, min_value, ...)	Message containing ventilation control parameters.
`SensorValues`([timestamp, loop_counter, ...])	Structured class for communicating sensor readings throughout PVP.

Functions:

init_logger(module_name[, log_level, ...])	Initialize a logger for logging events.
pformat(object[, indent, width, depth, compact])	Format a Python object into a pretty-printed representation.

class pvp.alarm.alarm_manager.**Alarm_Manager**

The Alarm Manager

The alarm manager receives *SensorValues* from the GUI via *Alarm_Manager.update()* and emits *Alarm* s to methods given by *Alarm_Manager.add_callback()* . When alarm limits are updated (ie. the *Alarm_Rule* has *depends*), it emits them to methods registered with *Alarm_Manager.add_dependency_callback()* .

On initialization, the alarm manager calls *Alarm_Manager.load_rules()* , which loads all rules defined in *alarm.ALARM_RULES* .

active_alarms

{*AlarmType*: *Alarm*}

Type dict

logged_alarms

A list of deactivated alarms.

Type list

dependencies

A dictionary mapping *ValueName* s to the alarm threshold dependencies they update

Type dict

pending_clears

[*AlarmType*] list of alarms that have been requested to be cleared

Type list

callbacks

list of callables that accept *Alarm* s when they are raised/altered.

Type list

cleared_alarms

of *AlarmType* s, alarms that have been cleared but have not dropped back into the 'off' range to enable re-raising

Type list

snoozed_alarms

of *AlarmType* s : times, alarms that should not be raised because they have been silenced for a period of time

Type dict

callbacks

list of callables to send *Alarm* objects to

Type list

depends_callbacks

When we *update_dependencies()*, we send back a *ControlSetting* with the new min/max

Type list

rules

A dict mapping `AlarmType` to `Alarm_Rule`.

Type dict

If an Alarm_Manager already exists, when initing just return that one

Attributes:

`_instance`
`active_alarms`
`callbacks`
`cleared_alarms`
`dependencies`
`depends_callbacks`
`logged_alarms`
`logger`
`pending_clears`
`rules`
`snoozed_alarms`

Methods:

`add_callback`(callback)	Assert we're being given a callable and add it to our list of callbacks.
`add_dependency_callback`(callback)	Assert we're being given a callable and add it to our list of dependency_callbacks
`check_rule`(rule, sensor_values)	`check()` the alarm rule, handle logic of raising, emitting, or lowering an alarm.
`clear_all_alarms`()	call `Alarm_Manager.deactivate_alarm()` for all active alarms.
`deactivate_alarm`(alarm)	Mark an alarm's internal active flags and remove from `active_alarms`
`dismiss_alarm`(alarm_type[, duration])	GUI or other object requests an alarm to be dismissed & deactivated
`emit_alarm`(alarm_type, severity)	Emit alarm (by calling all callbacks with it).
`get_alarm_severity`(alarm_type)	Get the severity of an Alarm
`load_rule`(alarm_rule)	Add the Alarm Rule to `Alarm_Manager.rules` and register any dependencies they have with `Alarm_Manager.register_dependency()`
`load_rules`()	Copy alarms from `alarm.ALARM_RULES` and call `Alarm_Manager.load_rule()` for each
`register_alarm`(alarm)	Be given an already created alarm and emit to callbacks.
`register_dependency`(condition, dependency, . . .)	Add dependency in a Condition object to be updated when values are changed
`reset`()	Reset all conditions, callbacks, and other stateful attributes and clear alarms
`update`(sensor_values)	Call `Alarm_Manager.check_rule()` for all rules in `Alarm_Manager.rules`
`update_dependencies`(control_setting)	Update Condition objects that update their value according to some control parameter

_instance = None

active_alarms: Dict[*pvp.alarm.AlarmType*, *pvp.alarm.alarm.Alarm*] = {}

logged_alarms: List[*pvp.alarm.alarm.Alarm*] = []

dependencies = {}

pending_clears = []

cleared_alarms = []

snoozed_alarms = {}

callbacks = []

depends_callbacks = []

rules = {}

logger = <Logger pvp.alarm.alarm_manager (WARNING)>

load_rules()
Copy alarms from `alarm.ALARM_RULES` and call `Alarm_Manager.load_rule()` for each

load_rule(*alarm_rule:* pvp.alarm.rule.Alarm_Rule)
Add the Alarm Rule to `Alarm_Manager.rules` and register any dependencies they have with `Alarm_Manager.register_dependency()`

Parameters **alarm_rule** (`Alarm_Rule`) – Alarm rule to be loaded

update(*sensor_values:* pvp.common.message.SensorValues)
Call `Alarm_Manager.check_rule()` for all rules in `Alarm_Manager.rules`

Parameters **sensor_values** (`SensorValues`) – New sensor values from the GUI

check_rule(*rule:* pvp.alarm.rule.Alarm_Rule, *sensor_values:* pvp.common.message.SensorValues)
`check()` the alarm rule, handle logic of raising, emitting, or lowering an alarm.

When alarms are dismissed, an `alarm.Alarm` is emitted with `AlarmSeverity.OFF` .

- If the alarm severity has increased, emit a new alarm.
- If the alarm severity has decreased and the alarm is not latched, emit a new alarm
- If the alarm severity has decreased and the alarm is latched, check if the alarm has been manually dismissed, if it has emit a new alarm.
- If a latched alarm has been manually dismissed previously and the alarm condition is now no longer met, dismiss the alarm.

Parameters

- **rule** (`Alarm_Rule`) – Alarm rule to check
- **sensor_values** (`SensorValues`) – sent by the GUI to check against alarm rule

emit_alarm(*alarm_type:* pvp.alarm.AlarmType, *severity:* pvp.alarm.AlarmSeverity)
Emit alarm (by calling all callbacks with it).

Note: This method emits *and* clears alarms – a cleared alarm is emitted with `AlarmSeverity.OFF`

Parameters

- **alarm_type** (*AlarmType*) –
- **severity** (*AlarmSeverity*) –

deactivate_alarm (*alarm: (<enum 'AlarmType'>, <class 'pvp.alarm.alarm.Alarm'>)*)
Mark an alarm's internal active flags and remove from `active_alarms`

Typically called internally when an alarm is being replaced by one of the same type but a different severity.

Note: This does *not* alert listeners that an alarm has been cleared, for that emit an alarm with AlarmSeverity.OFF

Parameters **alarm** (*AlarmType* , *Alarm*) – Alarm to deactivate

dismiss_alarm (*alarm_type:* pvp.alarm.AlarmType, *duration:* *float* = *None*)
GUI or other object requests an alarm to be dismissed & deactivated

GUI will wait until it receives an *emit_alarm* of severity == OFF to remove alarm widgets. If the alarm is not latched

If the alarm is latched, alarm_manager will not decrement alarm severity or emit *OFF* until a) the condition returns to *OFF*, and b) the user dismisses the alarm

Parameters

- **alarm_type** (*AlarmType*) – Alarm to dismiss
- **duration** (*float*) – seconds - amount of time to wait before alarm can be re-raised If a duration is provided, the alarm will not be able to be re-raised

get_alarm_severity (*alarm_type:* pvp.alarm.AlarmType)
Get the severity of an Alarm

Parameters **alarm_type** (*AlarmType*) – Alarm type to check

Returns *AlarmSeverity*

register_alarm (*alarm:* pvp.alarm.alarm.Alarm)
Be given an already created alarm and emit to callbacks.

Mostly used during testing for programmatically created alarms. Creating alarms outside of the Alarm_Manager is generally discouraged.

Parameters **alarm** (*Alarm*) –

register_dependency (*condition:* pvp.alarm.condition.Condition, *dependency:* *dict*, *severity:* pvp.alarm.AlarmSeverity)
Add dependency in a Condition object to be updated when values are changed

Parameters

- **condition** (*dict*) – Condition as defined in an *Alarm_Rule*
- **dependency** (*dict*) – either a (ValueName, attribute_name) or optionally also + transformation callable
- **severity** (*AlarmSeverity*) – severity of dependency

update_dependencies (*control_setting:* pvp.common.message.ControlSetting)
Update Condition objects that update their value according to some control parameter

Call any `transform` functions on the attribute of the control setting specified in the depencency.

Emit another `ControlSetting` describing the new max or min or the value.

Parameters **control_setting** (*ControlSetting*) – Control setting that was changed

add_callback (*callback: Callable*)
Assert we're being given a callable and add it to our list of callbacks.

Parameters **callback** (*typing.Callable*) – Callback that accepts a single argument of an `Alarm`

add_dependency_callback (*callback: Callable*)
Assert we're being given a callable and add it to our list of dependency_callbacks

Parameters **callback** (*typing.Callable*) – Callback that accepts a `ControlSetting`

Returns:

clear_all_alarms ()
call `Alarm_Manager.deactivate_alarm()` for all active alarms.

reset ()
Reset all conditions, callbacks, and other stateful attributes and clear alarms

14.2.2 Alarm Objects

Alarm objects represent the state and severity of active alarms, but are otherwise intentionally quite featureless.

They are created and maintained by the `Alarm_Manager` and sent to any listeners registered in `Alarm_Manager.callbacks`.

Classes:

`Alarm`(alarm_type, severity, start_time, ...)	Representation of alarm status and parameters
`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
`count`	count(start=0, step=1) –> count object
`datetime`(year, month, day[, hour[, minute[, ...)	The year, month and day arguments are required.

class pvp.alarm.alarm.**Alarm** (*alarm_type:* pvp.alarm.AlarmType, *severity:* pvp.alarm.AlarmSeverity, *start_time: float = None*, *latch: bool = True*, *cause: list = None*, *value=None*, *message=None*)
Representation of alarm status and parameters

Parameterized by a `Alarm_Rule` and managed by `Alarm_Manager`

Parameters

- **alarm_type** (*AlarmType*) – Type of alarm
- **severity** (*AlarmSeverity*) – Severity of alarm
- **start_time** (*float*) – Timestamp of alarm start, (as generated by `time.time()`
- **cause** (ValueName) – The *ValueName* that caused the alarm to be fired
- **value** (*int, float*) – optional - numerical value that generated the alarm
- **message** (*str*) – optional - override default text generated by `AlarmManager`

id
unique alarm ID

Type int

end_time
If None, alarm has not ended. otherwise timestamp

Type None, float

active
Whether or not the alarm is currently active

Type bool

Methods:

`__init__`(alarm_type, severity[, start_time, . . .])	**param alarm_type** Type of alarm
`deactivate`()	If active, register an end time and set as `active == False` Returns:

Attributes:

`alarm_type`	Alarm Type, property without setter to prevent change after instantiation
`id_counter`	used to generate unique IDs for each alarm
`severity`	Alarm Severity, property without setter to prevent change after instantiation

id_counter = count(0)
used to generate unique IDs for each alarm

Type `itertools.count`

__init__(*alarm_type: pvp.alarm.AlarmType*, *severity: pvp.alarm.AlarmSeverity*, *start_time: float = None*, *latch: bool = True*, *cause: list = None*, *value=None*, *message=None*)

Parameters

- **alarm_type** (`AlarmType`) – Type of alarm
- **severity** (`AlarmSeverity`) – Severity of alarm
- **start_time** (`float`) – Timestamp of alarm start, (as generated by `time.time()`
- **cause** (`ValueName`) – The `ValueName` that caused the alarm to be fired
- **value** (`int, float`) – optional - numerical value that generated the alarm
- **message** (`str`) – optional - override default text generated by `AlarmManager`

id
unique alarm ID
Type int

end_time
If None, alarm has not ended. otherwise timestamp
Type None, float

active
Whether or not the alarm is currently active
Type bool

property severity
Alarm Severity, property without setter to prevent change after instantiation

Returns *AlarmSeverity*

property alarm_type
Alarm Type, property without setter to prevent change after instantiation

Returns *AlarmType*

deactivate()
If active, register an end time and set as `active == False` Returns:

14.2.3 Alarm Rule

One *Alarm_Rule* is defined for each *AlarmType* in *ALARM_RULES*.

An alarm rule defines:

- The conditions for raising different severities of an alarm
- The dependencies between set values and alarm thresholds
- The behavior of the alarm, specifically whether it is `latch` ed.

14.2.3.1 Example

As an example, we'll define a `LOW_PRESSURE` alarm with escalating severity. A `LOW` severity alarm will be raised when measured `PIP` falls 10% below set `PIP`, which will escalate to a `MEDIUM` severity alarm if measured `PIP` falls 15% below set `PIP` **and** the `LOW` severity alarm has been active for at least two breath cycles.

First we define the name and behavior of the alarm:

```
Alarm_Rule(
    name = AlarmType.LOW_PRESSURE,
    latch = False,
```

In this case, `latch == False` means that the alarm will disappear (or be downgraded in severity) whenever the conditions for that alarm are no longer met. If `latch == True`, an alarm requires manual dismissal before it is downgraded or disappears.

Next we'll define a tuple of *Condition* objects for `LOW` and `MEDIUM` severity objects.

Starting with the `LOW` severity alarm:

```
conditions = (
     (
    AlarmSeverity.LOW,
    condition.ValueCondition(
        value_name=ValueName.PIP,
        limit=VALUES[ValueName.PIP]['safe_range'][0],
        mode='min',
        depends={
            'value_name': ValueName.PIP,
            'value_attr': 'value',
            'condition_attr': 'limit',
            'transform': lambda x : x-(x*0.10)
        })
```

(continues on next page)

(continued from previous page)

```
    ),
    # ... continued in next block
```

Each condition is a tuple of an (*AlarmSeverity*, *Condition*). In this case, we use a *ValueCondition* which tests whether a value is above or below a set `'max'` or `'min'`, respectively. For the low severity `LOW_PRESSURE` alarm, we test if `ValueName.PIP` is below (`mode='min'`) some `limit`, which is initialized as the low-end of `PIP`'s safe range.

We also define a condition for updating the `'limit'` of the condition (`'condition_attr' : 'limit'`), from the `ControlSetting.value`` field whenever `PIP` is updated. Specifically, we set the `limit` to be 10% less than the set `PIP` value by 10% with a lambda function (`lambda x : x-(x*0.10)`).

Next, we define the `MEDIUM` severity alarm condition:

```
(
AlarmSeverity.MEDIUM,
condition.ValueCondition(
    value_name=ValueName.PIP,
    limit=VALUES[ValueName.PIP]['safe_range'][0],
    mode='min'
    depends={
        'value_name': ValueName.PIP,
        'value_attr': 'value',
        'condition_attr': 'limit',
        'transform': lambda x: x - (x * 0.15)
    },
) + \
condition.CycleAlarmSeverityCondition(
    alarm_type = AlarmType.LOW_PRESSURE,
    severity   = AlarmSeverity.LOW,
    n_cycles = 2
))
```

The first `ValueCondition` is the same as in the `LOW` alarm severity condition, except that it is set 15% below `PIP`.

A second *CycleAlarmSeverityCondition* has been added (with +) to the *ValueCondition* When conditions are added together, they will only return `True` (ie. trigger an alarm) if all of the conditions are met. This condition checks that the `LOW_PRESSURE` alarm has been active at a `LOW` severity for at least two cycles.

Full source for this example and all alarm rules can be found here

14.2.3.2 Module Documentation

Class to declare alarm rules

Classes:

`AlarmSeverity`(value)	An enumeration.
`AlarmType`(value)	An enumeration.
Alarm_Rule(name, conditions[, latch, technical])	• name of rule
`ValueName`(value)	Canonical names of all values used in PVP.

class pvp.alarm.rule.**Alarm_Rule**(*name: pvp.alarm.AlarmType*, *conditions*, *latch=True*, *technical=False*)

- name of rule
- conditions: ((alarm_type, (condition_1, condition_2)), . . .)
- latch (bool): if True, alarm severity cannot be decremented until user manually dismisses
- silencing/overriding rules

Methods:

check(sensor_values)	Check all of our `conditions` .
reset()	

Attributes:

depends	Get all ValueNames whose alarm limits depend on this alarm rule :returns: list[ValueName]
severity	Last Alarm Severity from `.check()` :returns: *AlarmSeverity*
value_names	Get all ValueNames specified as value_names in alarm conditions

check (*sensor_values*)
Check all of our `conditions` .

Parameters **sensor_values** –

Returns:

property severity
Last Alarm Severity from `.check()` :returns: *AlarmSeverity*

reset ()

property depends
Get all ValueNames whose alarm limits depend on this alarm rule :returns: list[ValueName]

property value_names
Get all ValueNames specified as value_names in alarm conditions

Returns list[ValueName]

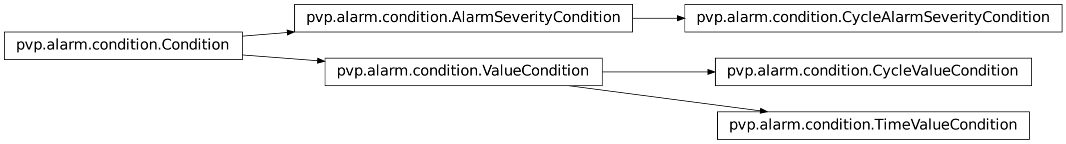
14.2.4 Alarm Condition

Condition objects define conditions that can raise alarms. They are used by *Alarm_Rule* s.

Each has to define a *Condition.check()* method that accepts *SensorValues* . The method should return `True` if the alarm condition is met, and `False` otherwise.

Conditions can be added (+) together to make compound conditions, and a single call to `check` will only return true if both conditions return true. If any condition in the chain returns false, evaluation is stopped and the alarm is not raised.

Conditions can



Classes:

AlarmSeverity(value)	An enumeration.
AlarmSeverityCondition(alarm_type, severity, …)	Alarm is above or below a certain severity.
AlarmType(value)	An enumeration.
Condition(depends, *args, **kwargs)	Base class for specifying alarm test conditions
CycleAlarmSeverityCondition(n_cycles, *args, …)	alarm goes out of range for a specific number of breath cycles
CycleValueCondition(n_cycles, *args, **kwargs)	Value goes out of range for a specific number of breath cycles
SensorValues([timestamp, loop_counter, …])	Structured class for communicating sensor readings throughout PVP.
TimeValueCondition(time, *args, **kwargs)	value goes out of range for specific amount of time
ValueCondition(value_name, limit, mode, …)	Value is greater or lesser than some max/min
ValueName(value)	Canonical names of all values used in PVP.

Functions:

get_alarm_manager()

pvp.alarm.condition.**get_alarm_manager**()

class pvp.alarm.condition.**Condition**(*depends: dict = None*, **args*, ***kwargs*)

Bases: object

Base class for specifying alarm test conditions

Subclasses must define *Condition.check()* and Conditino.reset()

Condition objects can be added together to create compound conditions.

_child

if another condition is added to this one, store a reference to it

Type *Condition*

Parameters

- **depends** (*list, dict*) – a list of, or a single dict:

```
{'value_name':ValueName,
'value_attr': attr in ControlMessage,
 'condition_attr',
 optional: transformation: callable)
that declare what values are needed to update
```

- ***args** –
- ****kwargs** –

Methods:

`__init__`([depends])	**param depends**
`check`(sensor_values)	Every Condition subclass needs to define this method that accepts `SensorValues` and returns a boolean
`reset`()	If a condition is stateful, need to provide some method of resetting the state

Attributes:

`manager`	The active alarm manager, used to get status of alarms

`__init__`(*depends: dict = None, *args, **kwargs*)

Parameters

- **depends** (`list, dict`) – a list of, or a single dict:

```
{'value_name':ValueName,
'value_attr': attr in ControlMessage,
 'condition_attr',
 optional: transformation: callable)
that declare what values are needed to update
```

- ***args** –
- ****kwargs** –

property manager

The active alarm manager, used to get status of alarms

Returns `pvp.alarm.alarm_manager.Alarm_Manager`

check(*sensor_values*) → bool

Every Condition subclass needs to define this method that accepts `SensorValues` and returns a boolean

Parameters **sensor_values** (`SensorValues`) – SensorValues used to compute alarm status

Returns bool

reset()

If a condition is stateful, need to provide some method of resetting the state

class pvp.alarm.condition.**ValueCondition**(*value_name: pvp.common.values.ValueName, limit: (<class 'int'>, <class 'float'>), mode: str, *args, **kwargs*)

Bases: `pvp.alarm.condition.Condition`

Value is greater or lesser than some max/min

Parameters

- **value_name** (`ValueName`) – Which value to check
- **limit** (*int*, *float*) – value to check against
- **mode** (*'min'*, *'max'*) – whether the limit is a minimum or maximum
- ***args** –
- ****kwargs** –

operator
Either the less than or greater than operators, depending on whether mode is `'min'` or `'max'`

Type callable

Methods:

`__init__`(value_name, limit, mode, *args, …)	**param value_name** Which value to check
`check`(sensor_values)	Check that the relevant value in SensorValues is either greater or lesser than the limit
`reset`()	not stateful, do nothing.

Attributes:

`mode`	One of 'min' or 'max', defines how the incoming sensor values are compared to the set value

__init__(*value_name: pvp.common.values.ValueName, limit: (<class 'int'>, <class 'float'>), mode: str, *args, **kwargs*)

Parameters

- **value_name** (`ValueName`) – Which value to check
- **limit** (*int*, *float*) – value to check against
- **mode** (*'min'*, *'max'*) – whether the limit is a minimum or maximum
- ***args** –
- ****kwargs** –

operator
Either the less than or greater than operators, depending on whether mode is `'min'` or `'max'`
Type callable

property mode
One of 'min' or 'max', defines how the incoming sensor values are compared to the set value

Returns:

check(*sensor_values*)
Check that the relevant value in SensorValues is either greater or lesser than the limit

Parameters sensor_values (*SensorValues*) –

Returns bool

reset()
not stateful, do nothing.

class pvp.alarm.condition.**CycleValueCondition**(*n_cycles: int*, **args*, ***kwargs*)
Bases: *pvp.alarm.condition.ValueCondition*

Value goes out of range for a specific number of breath cycles

Parameters n_cycles (*int*) – number of cycles required

_start_cycle
The breath cycle where the

Type int

_mid_check
whether a value has left the acceptable range and we are counting consecutive breath cycles

Type bool

Parameters

- **value_name** (ValueName) – Which value to check
- **limit** (*int, float*) – value to check against
- **mode** (*'min', 'max'*) – whether the limit is a minimum or maximum
- ***args** –
- ****kwargs** –

operator
Either the less than or greater than operators, depending on whether mode is 'min' or 'max'

Type callable

Methods:

check(sensor_values)	Check if outside of range, and then check if number of breath cycles have elapsed
reset()	Reset check status and start cycle

Attributes:

n_cycles	Number of cycles required

property n_cycles
Number of cycles required

check(*sensor_values*) → bool
Check if outside of range, and then check if number of breath cycles have elapsed

Parameters **()** (*sensor_values*) –

Returns bool

reset()
Reset check status and start cycle

class pvp.alarm.condition.**TimeValueCondition**(*time*, **args*, ***kwargs*)
Bases: *pvp.alarm.condition.ValueCondition*

value goes out of range for specific amount of time

> **Warning:** Not implemented!

Parameters

- **time** (*float*) – number of seconds value must be out of range
- ***args** –
- ****kwargs** –

Methods:

__init__(time, *args, **kwargs)	**param time** number of seconds value must be out of range
check(sensor_values)	Check that the relevant value in SensorValues is either greater or lesser than the limit
reset()	not stateful, do nothing.

__init__(*time, *args, **kwargs*)

Parameters

- **time** (*float*) – number of seconds value must be out of range
- ***args** –
- ****kwargs** –

check(*sensor_values*)

Check that the relevant value in SensorValues is either greater or lesser than the limit

Parameters **sensor_values** (*SensorValues*) –

Returns bool

reset()

not stateful, do nothing.

class pvp.alarm.condition.**AlarmSeverityCondition**(*alarm_type:* pvp.alarm.AlarmType, *severity:* pvp.alarm.AlarmSeverity, *mode:* *str* = *'min'*, **args*, ***kwargs*)

Bases: *pvp.alarm.condition.Condition*

Alarm is above or below a certain severity.

Get alarm severity status from *Alarm_Manager.get_alarm_severity()* .

Parameters

- **alarm_type** (*AlarmType*) – Alarm type to check
- **severity** (*AlarmSeverity*) – Alarm severity to check against
- **mode** (*str*) – one of 'min', 'equals', or 'max'. 'min' returns true if the alarm is at least this value (note the difference from ValueCondition which returns true if the alarm is less than..) and vice versa for 'max'.

> **Note:** 'min' and 'max' use >= and <= rather than > and <

- ***args** –
- ****kwargs** –

Methods:

__init__(alarm_type, severity[, mode])	Alarm is above or below a certain severity.
check(sensor_values)	Every Condition subclass needs to define this method that accepts *SensorValues* and returns a boolean
reset()	If a condition is stateful, need to provide some method of resetting the state

Attributes:

mode	'min' returns true if the alarm is at least this value (note the difference from ValueCondition which returns true if the alarm is less than..) and vice versa for 'max'.

__init__(*alarm_type: pvp.alarm.AlarmType*, *severity: pvp.alarm.AlarmSeverity*, *mode: str = 'min'*, **args*, ***kwargs*)

Alarm is above or below a certain severity.

Get alarm severity status from *Alarm_Manager.get_alarm_severity()* .

Parameters

- **alarm_type** (*AlarmType*) – Alarm type to check
- **severity** (*AlarmSeverity*) – Alarm severity to check against
- **mode** (*str*) – one of 'min', 'equals', or 'max'. 'min' returns true if the alarm is at least this value (note the difference from ValueCondition which returns true if the alarm is less than..) and vice versa for 'max'.

  Note: 'min' and 'max' use >= and <= rather than > and <

- ***args** –
- ****kwargs** –

property mode

'min' returns true if the alarm is at least this value (note the difference from ValueCondition which returns true if the alarm is less than..) and vice versa for 'max'.

Note: 'min' and 'max' use >= and <= rather than > and <

Returns one of 'min', 'equals', or 'max'.

Return type str

check(*sensor_values*)

Every Condition subclass needs to define this method that accepts *SensorValues* and returns a boolean

Parameters **sensor_values** (*SensorValues*) – SensorValues used to compute alarm status

Returns bool

reset()

If a condition is stateful, need to provide some method of resetting the state

class pvp.alarm.condition.**CycleAlarmSeverityCondition**(*n_cycles*, **args*, ***kwargs*)

Bases: *pvp.alarm.condition.AlarmSeverityCondition*

alarm goes out of range for a specific number of breath cycles

Todo: note that this is exactly the same as CycleValueCondition. Need to do the multiple inheritance thing

_start_cycle

The breath cycle where the

Type int

_mid_check

whether a value has left the acceptable range and we are counting consecutive breath cycles

Type bool

Alarm is above or below a certain severity.

Get alarm severity status from *Alarm_Manager.get_alarm_severity()* .

Parameters

- **alarm_type** (*AlarmType*) – Alarm type to check
- **severity** (*AlarmSeverity*) – Alarm severity to check against
- **mode** (*str*) – one of 'min', 'equals', or 'max'. 'min' returns true if the alarm is at least this value (note the difference from ValueCondition which returns true if the alarm is less than..) and vice versa for 'max'.

  Note: 'min' and 'max' use >= and <= rather than > and <

- ***args** –
- ****kwargs** –

Methods:

check(sensor_values)	Every Condition subclass needs to define this method that accepts *SensorValues* and returns a boolean
reset()	If a condition is stateful, need to provide some method of resetting the state

Attributes:

n_cycles

property n_cycles

check (*sensor_values*)
Every Condition subclass needs to define this method that accepts *SensorValues* and returns a boolean

Parameters **sensor_values** (*SensorValues*) – SensorValues used to compute alarm status

Returns bool

reset ()
If a condition is stateful, need to provide some method of resetting the state

14.3 Main Alarm Module

Data:

ALARM_RULES	Definitions of all *Alarm_Rule* s used by the *Alarm_Manager*

Classes:

Alarm(alarm_type, severity, start_time, ...)	Representation of alarm status and parameters
AlarmSeverity(value)	An enumeration.
AlarmType(value)	An enumeration.
Alarm_Manager()	The Alarm Manager
Alarm_Rule(name, conditions[, latch, technical])	• name of rule
Enum(value)	Generic enumeration.
IntEnum(value)	Enum where members are also (and must be) ints
ValueName(value)	Canonical names of all values used in PVP.
auto()	Instances are replaced with an appropriate value in Enum class suites.
odict	alias of collections.OrderedDict

class pvp.alarm.**AlarmType** (*value*)
An enumeration.

Attributes:

LOW_PRESSURE
HIGH_PRESSURE
LOW_VTE
HIGH_VTE
LOW_PEEP
HIGH_PEEP
LOW_O2
HIGH_O2
OBSTRUCTION
LEAK
SENSORS_STUCK
BAD_SENSOR_READINGS

continues on next page

Table 26 – continued from previous page

MISSED_HEARTBEAT	
human_name	Replace `.name` underscores with spaces

LOW_PRESSURE = 1

HIGH_PRESSURE = 2

LOW_VTE = 3

HIGH_VTE = 4

LOW_PEEP = 5

HIGH_PEEP = 6

LOW_O2 = 7

HIGH_O2 = 8

OBSTRUCTION = 9

LEAK = 10

SENSORS_STUCK = 11

BAD_SENSOR_READINGS = 12

MISSED_HEARTBEAT = 13

property human_name
Replace `.name` underscores with spaces

class pvp.alarm.**AlarmSeverity**(*value*)
An enumeration.

Attributes:

HIGH
MEDIUM
LOW
OFF
TECHNICAL

HIGH = 3

MEDIUM = 2

LOW = 1

OFF = 0

TECHNICAL = -1

pvp.alarm.**ALARM_RULES = OrderedDict([(<AlarmType.LOW_PRESSURE: 1>, <pvp.alarm.rule.Alarm_Ru**
Definitions of all *Alarm_Rule* s used by the *Alarm_Manager*

See definitions here

CHAPTER

FIFTEEN

COORDINATOR MODULE

15.1 Submodules

15.2 coordinator

Classes:

`Alarm`(alarm_type, severity, start_time, . . .)	Representation of alarm status and parameters
`ControlSetting`(name, value, min_value, . . .)	Message containing ventilation control parameters.
`CoordinatorBase`([sim_mode])	
`CoordinatorLocal`([sim_mode])	**param sim_mode**
`CoordinatorRemote`([sim_mode])	
`ProcessManager`(sim_mode[, startCommandLine, . . .])	
`SensorValues`([timestamp, loop_counter, . . .])	Structured class for communicating sensor readings throughout PVP.
`ValueName`(value)	Canonical names of all values used in PVP.

Data:

`Dict`	The central part of internal API.
`List`	The central part of internal API.

Functions:

`get_coordinator`([single_process, sim_mode])	
`get_rpc_client`()	
`init_logger`(module_name[, log_level, . . .])	Initialize a logger for logging events.

class `pvp.coordinator.coordinator.`**`CoordinatorBase`**(*sim_mode=False*)

Bases: `object`

Methods:

`get_alarms`()

continues on next page

Table 4 – continued from previous page

get_control(control_setting_name)	
get_sensors()	
get_target_waveform()	
is_running()	
kill()	
set_breath_detection(breath_detection)	
set_control(control_setting)	
start()	
stop()	

get_sensors () → *pvp.common.message.SensorValues*

get_alarms () → Union[None, Tuple[*pvp.alarm.alarm.Alarm*]]

set_control (*control_setting:* pvp.common.message.ControlSetting)

get_control (*control_setting_name:* pvp.common.values.ValueName) → *pvp.common.message.ControlSetting*

set_breath_detection (*breath_detection: bool*)

get_target_waveform ()

start ()

is_running () → bool

kill ()

stop ()

class pvp.coordinator.coordinator.**CoordinatorLocal** (*sim_mode=False*)
Bases: *pvp.coordinator.coordinator.CoordinatorBase*

Parameters sim_mode –

_is_running
.set() when thread should stop

Type threading.Event

Methods:

__init__([sim_mode])	**param sim_mode**
get_alarms()	
get_control(control_setting_name)	
get_sensors()	
get_target_waveform()	
is_running()	Test whether the whole system is running
kill()	
set_breath_detection(breath_detection)	
set_control(control_setting)	
start()	Start the coordinator.
stop()	Stop the coordinator.

__init__ (*sim_mode=False*)

Parameters **sim_mode** –

_is_running

`.set()` when thread should stop

Type threading.Event

get_sensors() → *pvp.common.message.SensorValues*

get_alarms() → Union[None, Tuple[*pvp.alarm.alarm.Alarm*]]

set_control(*control_setting: pvp.common.message.ControlSetting*)

get_control(*control_setting_name: pvp.common.values.ValueName*) → *pvp.common.message.ControlSetting*

set_breath_detection(*breath_detection: bool*)

get_target_waveform()

start()

Start the coordinator. This does a soft start (not allocating a process).

is_running() → bool

Test whether the whole system is running

stop()

Stop the coordinator. This does a soft stop (not kill a process)

kill()

class pvp.coordinator.coordinator.**CoordinatorRemote**(*sim_mode=False*)

Bases: *pvp.coordinator.coordinator.CoordinatorBase*

Methods:

`get_alarms`()	
`get_control`(control_setting_name)	
`get_sensors`()	
`get_target_waveform`()	
`is_running`()	Test whether the whole system is running
`kill`()	Stop the coordinator and end the whole program
`set_breath_detection`(breath_detection)	
`set_control`(control_setting)	
`start`()	Start the coordinator.
`stop`()	Stop the coordinator.

get_sensors() → *pvp.common.message.SensorValues*

get_alarms() → Union[None, Tuple[*pvp.alarm.alarm.Alarm*]]

set_control(*control_setting: pvp.common.message.ControlSetting*)

get_control(*control_setting_name: pvp.common.values.ValueName*) → *pvp.common.message.ControlSetting*

set_breath_detection(*breath_detection: bool*)

get_target_waveform()

start()

Start the coordinator. This does a soft start (not allocating a process).

is_running() → bool

Test whether the whole system is running

stop()
Stop the coordinator. This does a soft stop (not kill a process)

kill()
Stop the coordinator and end the whole program

pvp.coordinator.coordinator.**get_coordinator**(*single_process=False*, *sim_mode=False*) → *pvp.coordinator.coordinator.CoordinatorBase*

15.3 ipc

Classes:

SimpleXMLRPCServer(addr[, requestHandler, . . .])	Simple XML-RPC server.

Functions:

get_alarms()	
get_control(control_setting_name)	
get_rpc_client()	
get_sensors()	
get_target_waveform()	
init_logger(module_name[, log_level, . . .])	Initialize a logger for logging events.
rpc_server_main(sim_mode, serve_event[, . . .])	
set_breath_detection(breath_detection)	
set_control(control_setting)	

pvp.coordinator.rpc.**get_sensors**()

pvp.coordinator.rpc.**get_alarms**()

pvp.coordinator.rpc.**set_control**(*control_setting*)

pvp.coordinator.rpc.**get_control**(*control_setting_name*)

pvp.coordinator.rpc.**set_breath_detection**(*breath_detection*)

pvp.coordinator.rpc.**get_target_waveform**()

pvp.coordinator.rpc.**rpc_server_main**(*sim_mode*, *serve_event*, *addr='localhost'*, *port=9533*)

pvp.coordinator.rpc.**get_rpc_client**()

15.4 process_manager

Classes:

ProcessManager(sim_mode[, startCommandLine, . . .])	

class pvp.coordinator.process_manager.**ProcessManager**(*sim_mode*, *startCommandLine=None*, *maxHeartbeatInterval=None*)

Bases: object

Methods:

heartbeat(timestamp)	
restart_process()	
start_process()	
try_stop_process()	

start_process()

try_stop_process()

restart_process()

heartbeat(*timestamp*)

CHAPTER

SIXTEEN

REQUIREMENTS

CHAPTER

SEVENTEEN

DATASHEETS & MANUALS

17.1 Manuals

- Hamilton T1 Quick Guide

17.2 Other Reference Material

- Hamilton UI Simulator

CHAPTER EIGHTEEN

SPECS

CHAPTER

NINETEEN

CHANGELOG

19.1 Version 0.0

19.1.1 v0.0.2 (April xxth, 2020)

- Refactored gui into a module, splitting `widgets`, `styles`, and `defaults`.

19.1.2 v0.0.1 (April 12th, 2020)

- Added changelog
- Moved requirements for building docs to *requirements_docs.txt* so regular program reqs are a bit lighter.
- added autosummaries
- added additional resources & documentation files, with examples for adding external files like pdfs

19.1.3 v0.0.0 (April 12th, 2020)

Example of a changelog entry!!!

- We fixed this
- and this
- and this

Warning: but we didn't do this thing

Todo: and we still have to do this other thing.

CHAPTER

TWENTY

CONTRIBUTING

CHAPTER

TWENTYONE

BUILDING THE DOCS

A very brief summary...

- Docs are configured to be built from `_docs` into `docs`.
- The main page is `index.rst` which links to the existing modules
- To add a new page, you can create a new `.rst` file if you are writing with Restructuredtext , or a *.md* file if you are writing with markdown.

21.1 Local Build

- `pip install -r requirements.txt`
- `cd _docs`
- `make html`

Documentation will be generated into `docs`

CHAPTER

TWENTYTWO

H1 HEADING 8-)

22.1 h2 Heading

22.1.1 h3 Heading

22.1.1.1 h4 Heading

h5 Heading

h6 Heading

22.2 Horizontal Rules

22.3 Emphasis

This is bold text

This is bold text

This is italic text

This is italic text

22.4 Blockquotes

> Blockquotes can also be nested…
>
> > …by using additional greater-than signs right next to each other…
> >
> > > …or with spaces between arrows.

22.5 Lists

Unordered

- Create a list by starting a line with `+`, `-`, or `*`
- Sub-lists are made by indenting 2 spaces:
  - Marker character change forces new list start:
    * Ac tristique libero volutpat at
    * Facilisis in pretium nisl aliquet
    * Nulla volutpat aliquam velit
- Very easy!

Ordered

1. Lorem ipsum dolor sit amet
2. Consectetur adipiscing elit
3. Integer molestie lorem at massa
4. You can use sequential numbers…
5. …or keep all the numbers as `1.`

22.6 Code

Inline `code`

Indented code

```
// Some comments
line 1 of code
line 2 of code
line 3 of code
```

Block code "fences"

```
Sample text here...
```

Syntax highlighting

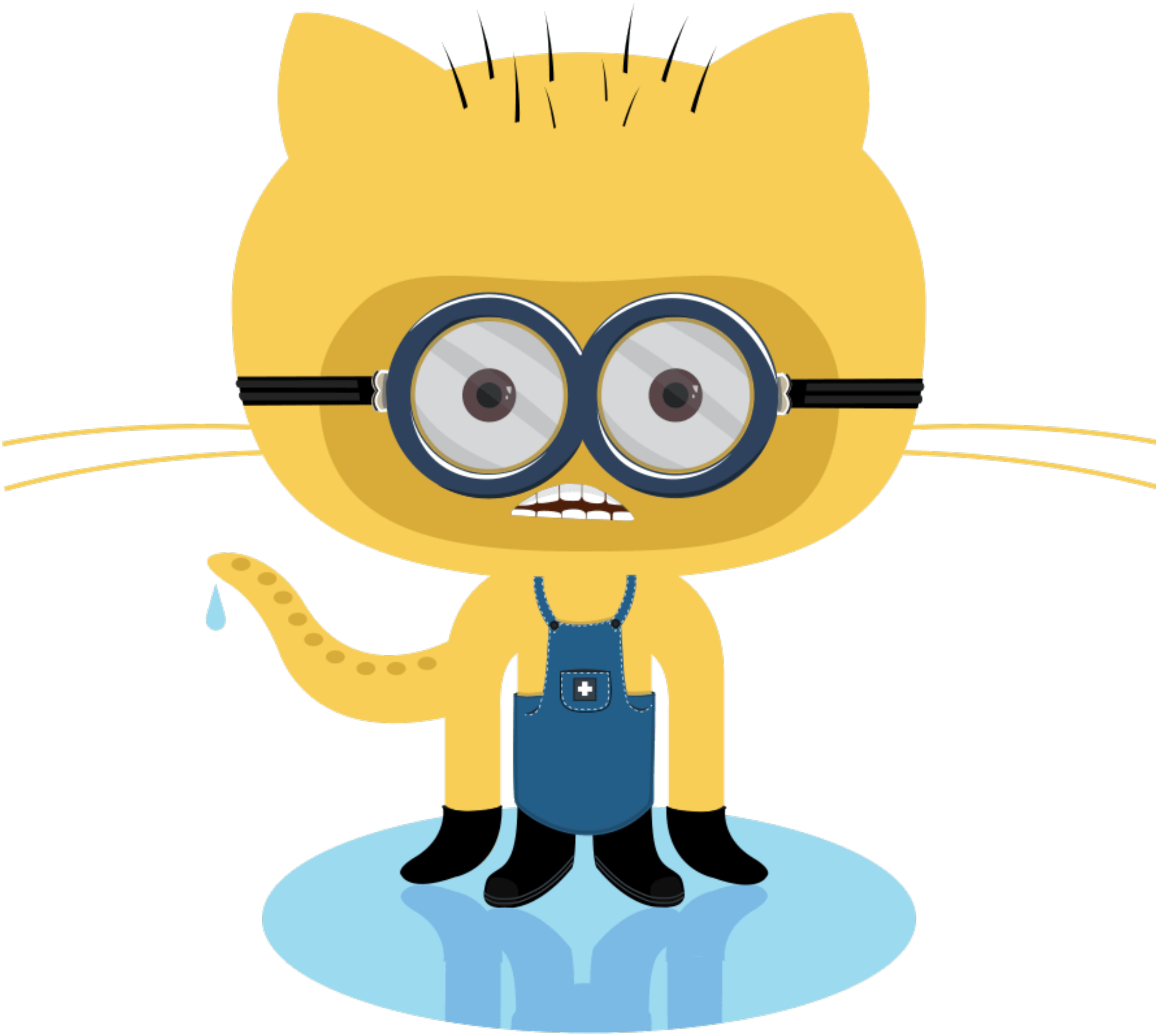
```
var foo = function (bar) {
  return bar++;
};

console.log(foo(5));
```

22.7 Links

link text

link with title

22.8 Images



Minion

Like links, Images also have a footnote style syntax

Alt text

With a reference later in the document defining the URL location:

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