# PyMeasure Documentation

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**PyMeasure Developers**

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# LEARNING PYMEASURE

PyMeasure makes scientific measurements easy to set up and run. The package contains a repository of instrument classes and a system for running experiment procedures, which provides graphical interfaces for graphing live data and managing queues of experiments. Both parts of the package are independent, and when combined provide all the necessary requirements for advanced measurements with only limited coding.

Installing Python and PyMeasure are demonstrated in the *Quick Start guide*. From there, checkout the existing *instruments that are available for use*.

PyMeasure is currently under active development, so please report any issues you experience on our Issues page.

The main documentation for the site is organized into a couple sections:

- *Learning PyMeasure*
- *API References*
- *About PyMeasure*

Information about development is also available:

- *Getting involved*

CHAPTER

ONE

# INTRODUCTION

PyMeasure uses an object-oriented approach for communicating with scientific instruments, which provides an intuitive interface where the low-level SCPI and GPIB commands are hidden from normal use. Users can focus on solving the measurement problems at hand, instead of re-inventing how to communicate with instruments.

Instruments with VISA (GPIB, Serial, etc) are supported through the PyVISA package under the hood. Prologix GPIB adapters are also supported. Communication protocols can be swapped, so that instrument classes can be used with all supported protocols interchangeably.

Before using PyMeasure, you may find it helpful to be acquainted with basic Python programming for the sciences and understand the concept of objects.

## 1.1 Instrument ready

The package includes a number of *instruments already defined*. Their definitions are organized based on the manufacturer name of the instrument. For example the class that defines the *Keithley 2400 SourceMeter* can be imported by calling:

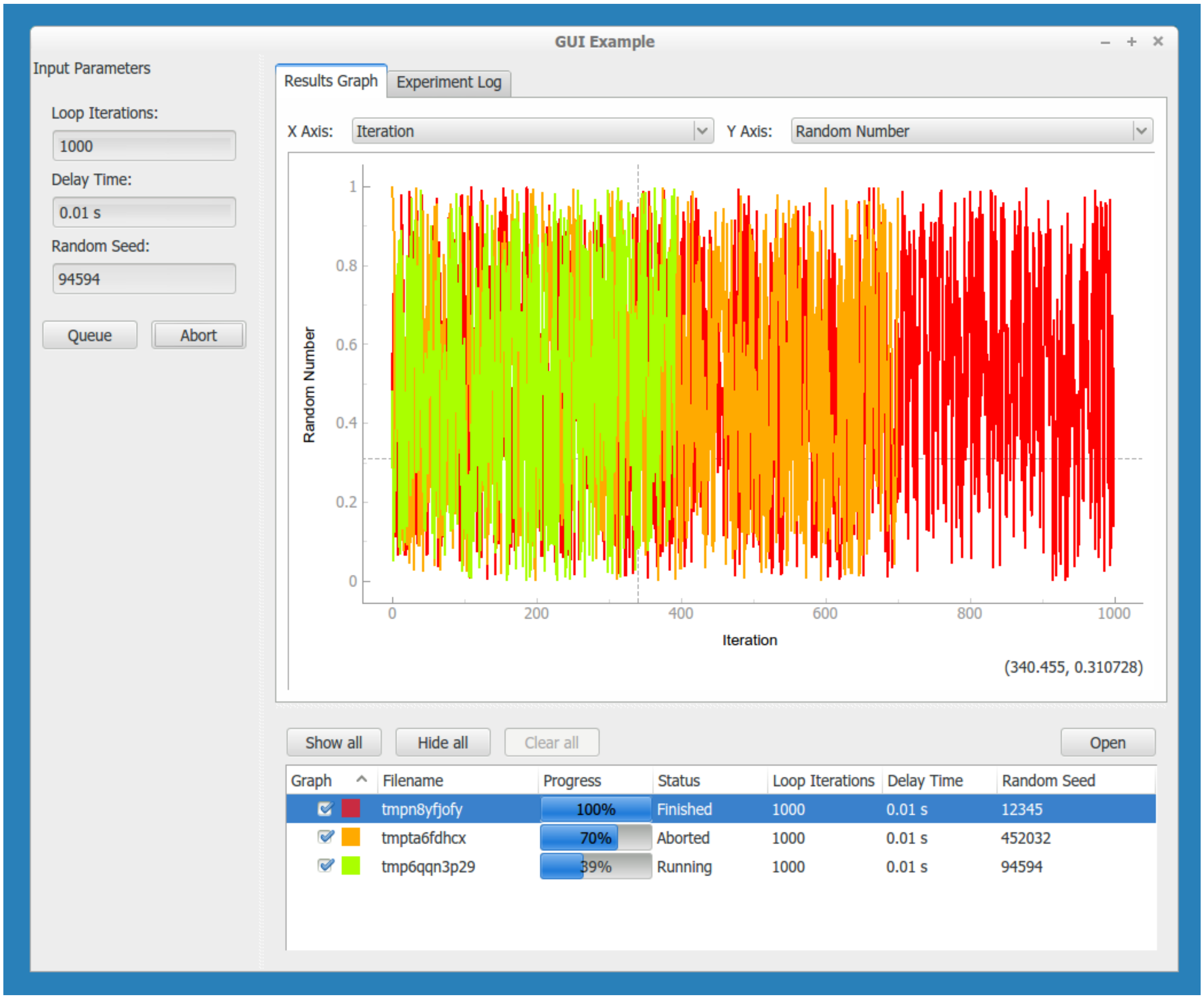
```
from pymeasure.instruments.keithley import Keithley2400
```

The *Tutorials* section will go into more detail on *connecting to an instrument*. If you don't find the instrument you are looking for, but are interested in contributing, see the documentation on *adding an instrument*.

## 1.2 Graphical displays

Graphical user interfaces (GUIs) can be easily generated to manage execution of measurement procedures with PyMeasure. This includes live plotting for data, and a queue system for managing large numbers of experiments.

These features are explored in the *Using a graphical interface* tutorial.


GUI Example
Input Parameters
Loop Iterations:
1000
Delay Time:
0.01 s
Random Seed:
94594
Queue
Abort
Results Graph
Experiment Log
X Axis:
Iteration
Y Axis:
Random Number
Random Number
Iteration
(340.455, 0.310728)
Show all
Hide all
Clear all
Open
Graph
Filename
Progress
Status
Loop Iterations
Delay Time
Random Seed
tmpn8yfjofy
100%
Finished
1000
0.01 s
12345
tmpta6fdhcx
70%
Aborted
1000
0.01 s
452032
tmp6qqn3p29
39%
Running
1000
0.01 s
94594

CHAPTER

TWO

# QUICK START

This section provides instructions for getting up and running quickly with PyMeasure.

## 2.1 Setting up Python

The easiest way to install the necessary Python environment for PyMeasure is through the Anaconda distribution, which includes 720 scientific packages. The advantage of using this approach over just relying on the `pip` installer is that it Anaconda correctly installs the required Qt libraries.

Download and install the appropriate Python version of Anaconda for your operating system.

## 2.2 Installing PyMeasure

### 2.2.1 Install with conda

If you have the Anaconda distribution you can use the conda package mangager to easily install PyMeasure and all required dependencies.

Open a terminal and type the following commands (on Windows look for the *Anaconda Prompt* in the Start Menu):

```
conda config --add channels conda-forge
conda install pymeasure
```

This will install PyMeasure and all the required dependencies.

### 2.2.2 Install with `pip`

PyMeasure can also be installed with `pip`.

```
pip install pymeasure
```

Depending on your operating system, using this method may require additional work to install the required dependencies, which include the Qt libaries.

### 2.2.3 Checking the version

Now that you have Python and PyMeasure installed, open up a "Jupyter Notebook" to test which version you have installed. Execute the following code into a notebook cell.

```
import pymeasure
pymeasure.__version__
```

You should see the version of PyMeasure printed out. At this point you have PyMeasure installed, and you are ready to start using it! Are you ready to *connect to an instrument*?

# CHAPTER THREE

# TUTORIALS

The following sections provide instructions for getting started with PyMeasure.

## 3.1 Connecting to an instrument

After following the *Quick Start* section, you now have a working installation of PyMeasure. This section describes connecting to an instrument, using a Keithley 2400 SourceMeter as an example. To follow the tutorial, open a command prompt, IPython terminal, or Jupyter notebook.

First import the instrument of interest.

```
from pymeasure.instruments.keithley import Keithley2400
```

Then construct an object by passing the GPIB address. For this example we connect to the instrument over GPIB (using VISA) with an address of 4. See the *adapters* section below for more details.

```
sourcemeter = Keithley2400("GPIB::4")
```

For instruments with standard SCPI commands, an `id` property will return the results of a `*IDN?` SCPI command, identifying the instrument.

```
sourcemeter.id
```

This is equivalent to manually calling the SCPI command.

```
sourcemeter.ask("*IDN?")
```

Here the `ask` method writes the SCPI command, reads the result, and returns that result. This is further equivalent to calling the methods below.

```
sourcemeter.write("*IDN?")
sourcemeter.read()
```

This example illustrates that the top-level methods like `id` are really composed of many lower-level methods. Both can be called depending on the operation that is desired. PyMeasure hides the complexity of these lower-level operations, so you can focus on the bigger picture.

Instruments are also equipped to be used in a `with` statement.

```
with Keithley2400("GPIB::4") as sourcemeter:
    sourcemeter.id
```

When the `with`-block is exited, the `shutdown` method of the instrument will be called, turning the system into a safe state.

```
with Keithley2400("GPIB::4") as sourcemeter:
    sourcemeter.isShutdown == False
sourcemeter.isShutdown == True
```

### 3.1.1 Using adapters

PyMeasure supports a number of adapters, which are responsible for communicating with the underlying hardware. In the example above, we passed the string "GPIB::4" when constructing the instrument. By default this constructs a VISAAdapter class to connect to the instrument using VISA. Instead of passing a string, we could equally pass an adapter object.

```
from pymeasure.adapters import VISAAdapter

adapter = VISAAdapter("GPIB::4")
sourcemeter = Keithely2400(adapter)
```

To instead use a Prologix GPIB device connected on `/dev/ttyUSB0` (proper permissions are needed in Linux, see *ProligixAdapter*), the adapter is constructed in a similar way. Unlike the VISA adapter which is specific to each instrument, the Prologix adapter can be shared by many instruments. Therefore, they are addressed separately based on the GPIB address number when passing the adapter into the instrument construction.

```
from pymeasure.adapters import PrologixAdapter

adapter = PrologixAdapter('/dev/ttyUSB0')
sourcemeter = Keithley2400(adapter.gpib(4))
```

For instruments using serial communication that have particular settings that need to be matched, a custom *Adapter* sub-class can be made. For example, the LakeShore 425 Gaussmeter connects via USB, but uses particular serial communication settings. Therefore, a *LakeShoreUSBAdapter* class enables these requirements in the background.

```
from pymeasure.instruments.lakeshore import LakeShore425

gaussmeter = LakeShore425('/dev/lakeshore425')
```

Behind the scenes the `/dev/lakeshore425` port is passed to the *LakeShoreUSBAdapter*.

Some equipment may require the vxi-11 protocol for communication. An example would be a Agilent E5810B ethernet to GPIB bridge. To use this type equipment the python-vxi11 library has to be installed which is part of the extras package requirements.

```
from pymeasure.adapters import VXI11Adapter
from pymeasure.instruments import Instrument

adapter = VXI11Adapter("TCPIP::192.168.0.100::inst0::INSTR")
instr = Instrument(adapter, "my_instrument")
```

### 3.1.2 Modifying connection settings

Sometimes you want to tweak the connection settings when talking to a device. This might be because you have a non-standard device or connection, or are troubleshooting why a device does not reply.

When using a string or integer to connect to an instrument, a *VISAAdapter* is used internally. Additional settings need to be passed in as keyword arguments. For example, to use a fast baud rate on a quick connection when connecting to the Keithely2400 as above, do

```
sourcemeter = Keithley2400("ASRL2", timeout=500, baud_rate=115200)
```

This overrides any defaults that may be defined for the instrument, either generally valid ones like `timeout` or interface-specific ones like `baud_rate`.

If you use an invalid argument, either misspelled or not valid for the chosen interface, an exception will be raised.

When using a separately-created Adapter instance, you define any custom settings when creating the adapter. Any keyword arguments passed in are discarded.

---

The above examples illustrate different methods for communicating with instruments, using adapters to keep instrument code independent from the communication protocols. Next we present the methods for setting up measurements.

## 3.2 Making a measurement

This tutorial will walk you through using PyMeasure to acquire a current-voltage (IV) characteristic using a Keithley 2400. Even if you don't have access to this instrument, this tutorial will explain the method for making measurements with PyMeasure. First we describe using a simple script to make the measurement. From there, we show how *Procedure* objects greatly simplify the workflow, which leads to making the measurement with a graphical interface.

### 3.2.1 Using scripts

Scripts are a quick way to get up and running with a measurement in PyMeasure. For our IV characteristic measurement, we perform the following steps:

1) Import the necessary packages
2) Set the input parameters to define the measurement
3) Connect to the Keithley 2400
4) Set up the instrument for the IV characteristic
5) Allocate arrays to store the resulting measurements
6) Loop through the current points, measure the voltage, and record
7) Save the final data to a CSV file
8) Shutdown the instrument

These steps are expressed in code as follows.

```
# Import necessary packages
from pymeasure.instruments.keithley import Keithley2400
import numpy as np
import pandas as pd
```

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```python
from time import sleep

# Set the input parameters
data_points = 50
averages = 50
max_current = 0.01
min_current = -max_current

# Connect and configure the instrument
sourcemeter = Keithley2400("GPIB::4")
sourcemeter.reset()
sourcemeter.use_front_terminals()
sourcemeter.measure_voltage()
sourcemeter.config_current_source()
sleep(0.1) # wait here to give the instrument time to react
sourcemeter.set_buffer(averages)

# Allocate arrays to store the measurement results
currents = np.linspace(min_current, max_current, num=data_points)
voltages = np.zeros_like(currents)
voltage_stds = np.zeros_like(currents)

# Loop through each current point, measure and record the voltage
for i in range(data_points):
    sourcemeter.current = currents[i]
    sourcemeter.reset_buffer()
    sleep(0.1)
    sourcemeter.start_buffer()
    sourcemeter.wait_for_buffer()

    # Record the average and standard deviation
    voltages[i] = sourcemeter.means
    voltage_stds[i] = sourcemeter.standard_devs

# Save the data columns in a CSV file
data = pd.DataFrame({
    'Current (A)': currents,
    'Voltage (V)': voltages,
    'Voltage Std (V)': voltage_stds,
})
data.to_csv('example.csv')

sourcemeter.shutdown()
```

Running this example script will execute the measurement and save the data to a CSV file. While this may be sufficient for very basic measurements, this example illustrates a number of issues that PyMeasure solves. The issues with the script example include:

- The progress of the measurement is not transparent
- Input parameters are not associated with the data that is saved
- Data is not plotted during the execution (nor at all in this case)
- Data is only saved upon successful completion, which is otherwise lost

- Canceling a running measurement causes the system to end in a undetermined state
- Exceptions also end the system in an undetermined state

The `Procedure` class allows us to solve all of these issues. The next section introduces the `Procedure` class and shows how to modify our script example to take advantage of these features.

### 3.2.2 Using Procedures

The Procedure object bundles the sequence of steps in an experiment with the parameters required for its successful execution. This simple structure comes with huge benefits, since a number of convenient tools for making the measurement use this common interface.

Let's start with a simple example of a procedure which loops over a certain number of iterations. We make the SimpleProcedure object as a sub-class of Procedure, since SimpleProcedure *is a* Procedure.

```
from time import sleep
from pymeasure.experiment import Procedure
from pymeasure.experiment import IntegerParameter

class SimpleProcedure(Procedure):

    # a Parameter that defines the number of loop iterations
    iterations = IntegerParameter('Loop Iterations')

    # a list defining the order and appearance of columns in our data file
    DATA_COLUMNS = ['Iteration']

    def execute(self):
        """ Loops over each iteration and emits the current iteration,
        before waiting for 0.01 sec, and then checking if the procedure
        should stop
        """
        for i in range(self.iterations):
            self.emit('results', {'Iteration': i})
            sleep(0.01)
            if self.should_stop():
                break
```

At the top of the SimpleProcedure class we define the required Parameters. In this case, `iterations` is a IntegerParameter that defines the number of loops to perform. Inside our Procedure class we reference the value in the iterations Parameter by the class variable where the Parameter is stored (`self.iterations`). PyMeasure swaps out the Parameters with their values behind the scene, which makes accessing the values of parameters very convenient.

We define the data columns that will be recorded in a list stored in `DATA_COLUMNS`. This sets the order by which columns are stored in the file. In this example, we will store the Iteration number for each loop iteration.

The `execute` methods defines the main body of the procedure. Our example method consists of a loop over the number of iterations, in which we emit the data to be recorded (the Iteration number). The data is broadcast to any number of listeners by using the `emit` method, which takes a topic as the first argument. Data with the `'results'` topic and the proper data columns will be recorded to a file. The sleep function in our example provides two very useful features. The first is to delay the execution of the next lines of code by the time argument in units of seconds. The seconds is that during this delay time, the CPU is free to perform other code. Successful measurements often require the intelligent use of sleep to deal with instrument delays and ensure that the CPU is not hogged by a single script. After our delay, we check to see if the Procedure should stop by calling `self.should_stop()`. By checking this flag, the Procedure will react to a user canceling the procedure execution.

This covers the basic requirements of a Procedure object. Now let's construct our SimpleProcedure object with 100 iterations.

```
procedure = SimpleProcedure()
procedure.iterations = 100
```

Next we will show how to run the procedure.

### Running Procedures

A Procedure is run by a Worker object. The Worker executes the Procedure in a separate Python thread, which allows other code to execute in parallel to the procedure (e.g. a graphical user interface). In addition to performing the measurement, the Worker spawns a Recorder object, which listens for the `'results'` topic in data emitted by the Procedure, and writes those lines to a data file. The Results object provides a convenient abstraction to keep track of where the data should be stored, the data in an accessible form, and the Procedure that pertains to those results.

We first construct a Results object for our Procedure.

```
from pymeasure.experiment import Results

data_filename = 'example.csv'
results = Results(procedure, data_filename)
```

Constructing the Results object for our Procedure creates the file using the `data_filename`, and stores the Parameters for the Procedure. This allows the Procedure and Results objects to be reconstructed later simply by loading the file using `Results.load(data_filename)`. The Parameters in the file are easily readable.

We now construct a Worker with the Results object, since it contains our Procedure.

```
from pymeasure.experiment import Worker

worker = Worker(results)
```

The Worker publishes data and other run-time information through specific queues, but can also publish this information over the local network on a specific TCP port (using the optional `port` argument. Using TCP communication allows great flexibility for sharing information with Listener objects. Queues are used as the standard communication method because they preserve the data order, which is of critical importance to storing data accurately and reacting to the measurement status in order.

Now we are ready to start the worker.

```
worker.start()
```

This method starts the worker in a separate Python thread, which allows us to perform other tasks while it is running. When writing a script that should block (wait for the Worker to finish), we need to join the Worker back into the main thread.

```
worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
```

Let's put all the pieces together. Our SimpleProcedure can be run in a script by the following.

```
from time import sleep
from pymeasure.experiment import Procedure, Results, Worker
from pymeasure.experiment import IntegerParameter

```

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```
class SimpleProcedure(Procedure):

    # a Parameter that defines the number of loop iterations
    iterations = IntegerParameter('Loop Iterations')

    # a list defining the order and appearance of columns in our data file
    DATA_COLUMNS = ['Iteration']

    def execute(self):
        """ Loops over each iteration and emits the current iteration,
        before waiting for 0.01 sec, and then checking if the procedure
        should stop
        """
        for i in range(self.iterations):
            self.emit('results', {'Iteration': i})
            sleep(0.01)
            if self.should_stop():
                break

if __name__ == "__main__":
    procedure = SimpleProcedure()
    procedure.iterations = 100

    data_filename = 'example.csv'
    results = Results(procedure, data_filename)

    worker = Worker(results)
    worker.start()

    worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
```

Here we have included an if statement to only run the script if the __name__ is __main__. This precaution allows us to import the SimpleProcedure object without running the execution.

### Using Logs

Logs keep track of important details in the execution of a procedure. We describe the use of the Python logging module with PyMeasure, which makes it easy to document the execution of a procedure and provides useful insight when diagnosing issues or bugs.

Let's extend our SimpleProcedure with logging.

```
import logging
log = logging.getLogger(__name__)
log.addHandler(logging.NullHandler())

from time import sleep
from pymeasure.log import console_log
from pymeasure.experiment import Procedure, Results, Worker
from pymeasure.experiment import IntegerParameter

class SimpleProcedure(Procedure):
```

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```
    iterations = IntegerParameter('Loop Iterations')

    DATA_COLUMNS = ['Iteration']

    def execute(self):
        log.info("Starting the loop of %d iterations" % self.iterations)
        for i in range(self.iterations):
            data = {'Iteration': i}
            self.emit('results', data)
            log.debug("Emitting results: %s" % data)
            sleep(0.01)
            if self.should_stop():
                log.warning("Caught the stop flag in the procedure")
                break

if __name__ == "__main__":
    console_log(log)

    log.info("Constructing a SimpleProcedure")
    procedure = SimpleProcedure()
    procedure.iterations = 100

    data_filename = 'example.csv'
    log.info("Constructing the Results with a data file: %s" % data_filename)
    results = Results(procedure, data_filename)

    log.info("Constructing the Worker")
    worker = Worker(results)
    worker.start()
    log.info("Started the Worker")

    log.info("Joining with the worker in at most 1 hr")
    worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
    log.info("Finished the measurement")
```

First, we have imported the Python logging module and grabbed the logger using the `__name__` argument. This gives us logging information specific to the current file. Conversely, we could use the `''` argument to get all logs, including those of pymeasure. We use the `console_log` function to conveniently output the log to the console. Further details on how to use the logger are addressed in the Python logging documentation.

### Modifying our script

Now that you have a background on how to use the different features of the Procedure class, and how they are run, we will revisit our IV characteristic measurement using Procedures. Below we present the modified version of our example script, now as a IVProcedure class.

```
# Import necessary packages
from pymeasure.instruments.keithley import Keithley2400
from pymeasure.experiment import Procedure
from pymeasure.experiment import IntegerParameter, FloatParameter
```

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```python
from time import sleep

class IVProcedure(Procedure):

    data_points = IntegerParameter('Data points', default=50)
    averages = IntegerParameter('Averages', default=50)
    max_current = FloatParameter('Maximum Current', units='A', default=0.01)
    min_current = FloatParameter('Minimum Current', units='A', default=-0.01)

    DATA_COLUMNS = ['Current (A)', 'Voltage (V)', 'Voltage Std (V)']

    def startup(self):
        log.info("Connecting and configuring the instrument")
        self.sourcemeter = Keithley2400("GPIB::4")
        self.sourcemeter.reset()
        self.sourcemeter.use_front_terminals()
        self.sourcemeter.measure_voltage()
        self.sourcemeter.config_current_source()
        sleep(0.1) # wait here to give the instrument time to react
        self.sourcemeter.set_buffer(averages)

    def execute(self):
        currents = np.linspace(
            self.min_current,
            self.max_current,
            num=self.data_points
        )

        # Loop through each current point, measure and record the voltage
        for current in currents:
            log.info("Setting the current to %g A" % current)
            self.sourcemeter.current = current
            self.sourcemeter.reset_buffer()
            sleep(0.1)
            self.sourcemeter.start_buffer()
            log.info("Waiting for the buffer to fill with measurements")
            self.sourcemeter.wait_for_buffer()

            self.emit('results', {
                'Current (A)': current,
                'Voltage (V)': self.sourcemeter.means,
                'Voltage Std (V)': self.sourcemeter.standard_devs
            })
            sleep(0.01)
            if self.should_stop():
                log.info("User aborted the procedure")
                break

    def shutdown(self):
        self.sourcemeter.shutdown()
        log.info("Finished measuring")
```

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```
if __name__ == "__main__":
    console_log(log)

    log.info("Constructing an IVProcedure")
    procedure = IVProcedure()
    procedure.data_points = 100
    procedure.averages = 50
    procedure.max_current = -0.01
    procedure.min_current = 0.01

    data_filename = 'example.csv'
    log.info("Constructing the Results with a data file: %s" % data_filename)
    results = Results(procedure, data_filename)

    log.info("Constructing the Worker")
    worker = Worker(results)
    worker.start()
    log.info("Started the Worker")

    log.info("Joining with the worker in at most 1 hr")
    worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
    log.info("Finished the measurement")
```

At this point, you are familiar with how to construct a Procedure sub-class. The next section shows how to put these procedures to work in a graphical environment, where will have live-plotting of the data and the ability to easily queue up a number of experiments in sequence. All of these features come from using the Procedure object.

## 3.3 Using a graphical interface

In the previous tutorial we measured the IV characteristic of a sample to show how we can set up a simple experiment in PyMeasure. The real power of PyMeasure comes when we also use the graphical tools that are included to turn our simple example into a full-flegged user interface.

### 3.3.1 Using the Plotter

While it lacks the nice features of the ManagedWindow, the Plotter object is the simplest way of getting live-plotting. The Plotter takes a Results object and plots the data at a regular interval, grabbing the latest data each time from the file.

**Warning:** The example in this section is known to raise issues when executed: a *QApplication was not created in the main thread / nextEventMatchingMask should only be called from the Main Thread* warning is raised. While the example works without issues on some operating systems and python configurations, users are advised not to rely on the plotter while this issue is unresolved. Users can hence skip this example and continue with the *Using the ManagedWindow* section.

Let's extend our SimpleProcedure with a RandomProcedure, which generates random numbers during our loop. This example does not include instruments to provide a simpler example.

```python
import logging
log = logging.getLogger(__name__)
log.addHandler(logging.NullHandler())

import random
from time import sleep
from pymeasure.log import console_log
from pymeasure.display import Plotter
from pymeasure.experiment import Procedure, Results, Worker
from pymeasure.experiment import IntegerParameter, FloatParameter, Parameter

class RandomProcedure(Procedure):

    iterations = IntegerParameter('Loop Iterations')
    delay = FloatParameter('Delay Time', units='s', default=0.2)
    seed = Parameter('Random Seed', default='12345')

    DATA_COLUMNS = ['Iteration', 'Random Number']

    def startup(self):
        log.info("Setting the seed of the random number generator")
        random.seed(self.seed)

    def execute(self):
        log.info("Starting the loop of %d iterations" % self.iterations)
        for i in range(self.iterations):
            data = {
                'Iteration': i,
                'Random Number': random.random()
            }
            self.emit('results', data)
            log.debug("Emitting results: %s" % data)
            self.emit('progress', 100 * i / self.iterations)
            sleep(self.delay)
            if self.should_stop():
                log.warning("Caught the stop flag in the procedure")
                break


if __name__ == "__main__":
    console_log(log)

    log.info("Constructing a RandomProcedure")
    procedure = RandomProcedure()
    procedure.iterations = 100

    data_filename = 'random.csv'
    log.info("Constructing the Results with a data file: %s" % data_filename)
    results = Results(procedure, data_filename)

    log.info("Constructing the Plotter")
    plotter = Plotter(results)
    plotter.start()
```

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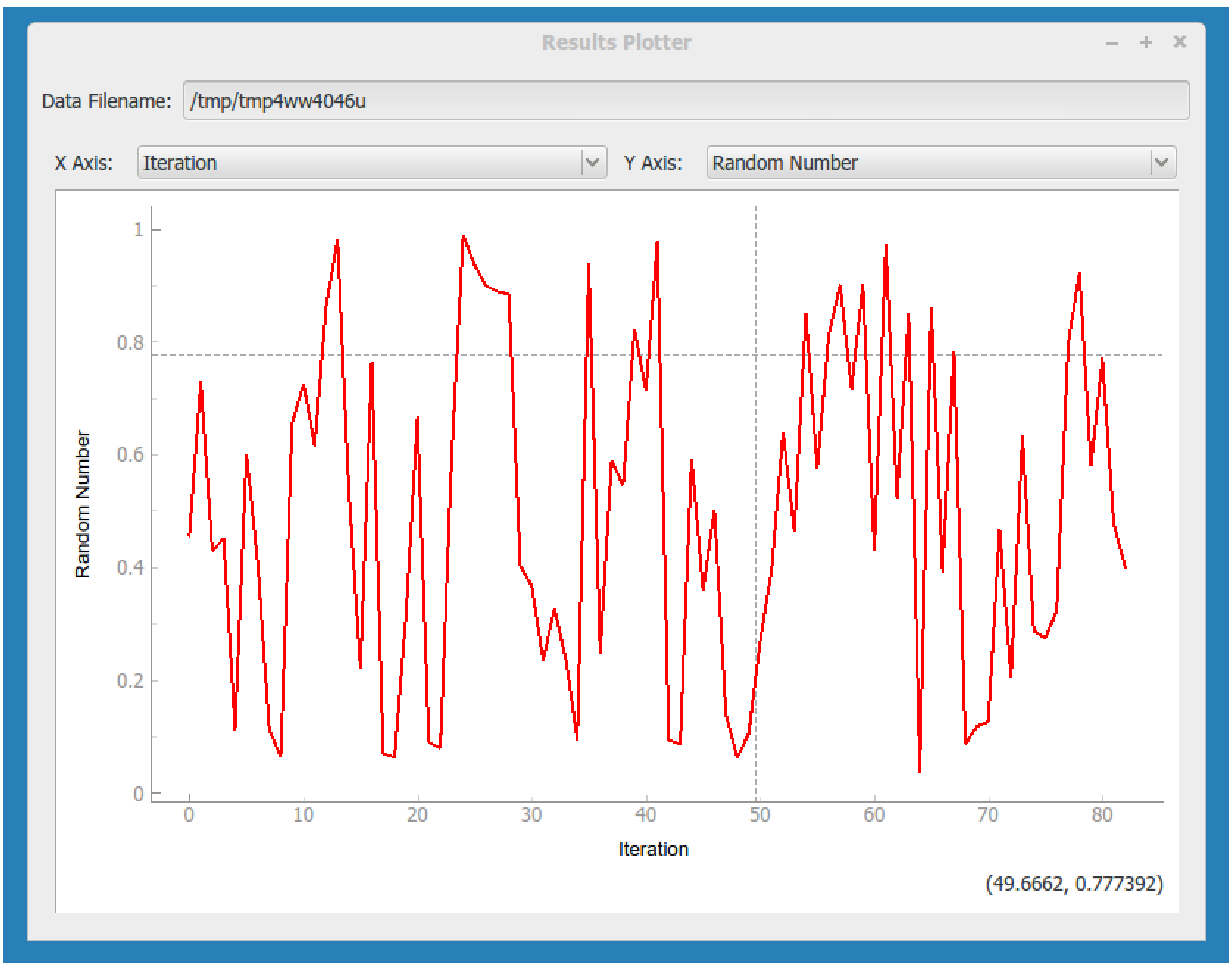
```
    log.info("Started the Plotter")

    log.info("Constructing the Worker")
    worker = Worker(results)
    worker.start()
    log.info("Started the Worker")

    log.info("Joining with the worker in at most 1 hr")
    worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
    log.info("Finished the measurement")
```

The important addition is the construction of the Plotter from the Results object.

```
plotter = Plotter(results)
plotter.start()
```

The Plotter is started in a different process so that it can be run on a separate CPU for higher performance. The Plotter launches a Qt graphical interface using pyqtgraph which allows the Results data to be viewed based on the columns in the data.



### 3.3.2 Using the ManagedWindow

The ManagedWindow is the most convenient tool for running measurements with your Procedure. This has the major advantage of accepting the input parameters graphically. From the parameters, a graphical form is automatically generated that allows the inputs to be typed in. With this feature, measurements can be started dynamically, instead of defined in a script.

Another major feature of the ManagedWindow is its support for running measurements in a sequential queue. This allows you to set up a number of measurements with different input parameters, and watch them unfold on the live-plot. This is especially useful for long running measurements. The ManagedWindow achieves this through the Manager object, which coordinates which Procedure the Worker should run and keeps track of its status as the Worker progresses.

Below we adapt our previous example to use a ManagedWindow.

```
import logging
log = logging.getLogger(__name__)
log.addHandler(logging.NullHandler())

import sys
import tempfile
import random
from time import sleep
from pymeasure.log import console_log
from pymeasure.display.Qt import QtGui
from pymeasure.display.windows import ManagedWindow
from pymeasure.experiment import Procedure, Results
from pymeasure.experiment import IntegerParameter, FloatParameter, Parameter

class RandomProcedure(Procedure):

    iterations = IntegerParameter('Loop Iterations')
    delay = FloatParameter('Delay Time', units='s', default=0.2)
    seed = Parameter('Random Seed', default='12345')

    DATA_COLUMNS = ['Iteration', 'Random Number']

    def startup(self):
        log.info("Setting the seed of the random number generator")
        random.seed(self.seed)

    def execute(self):
        log.info("Starting the loop of %d iterations" % self.iterations)
        for i in range(self.iterations):
            data = {
                'Iteration': i,
                'Random Number': random.random()
            }
            self.emit('results', data)
            log.debug("Emitting results: %s" % data)
            self.emit('progress', 100 * i / self.iterations)
            sleep(self.delay)
            if self.should_stop():
                log.warning("Caught the stop flag in the procedure")
                break
```

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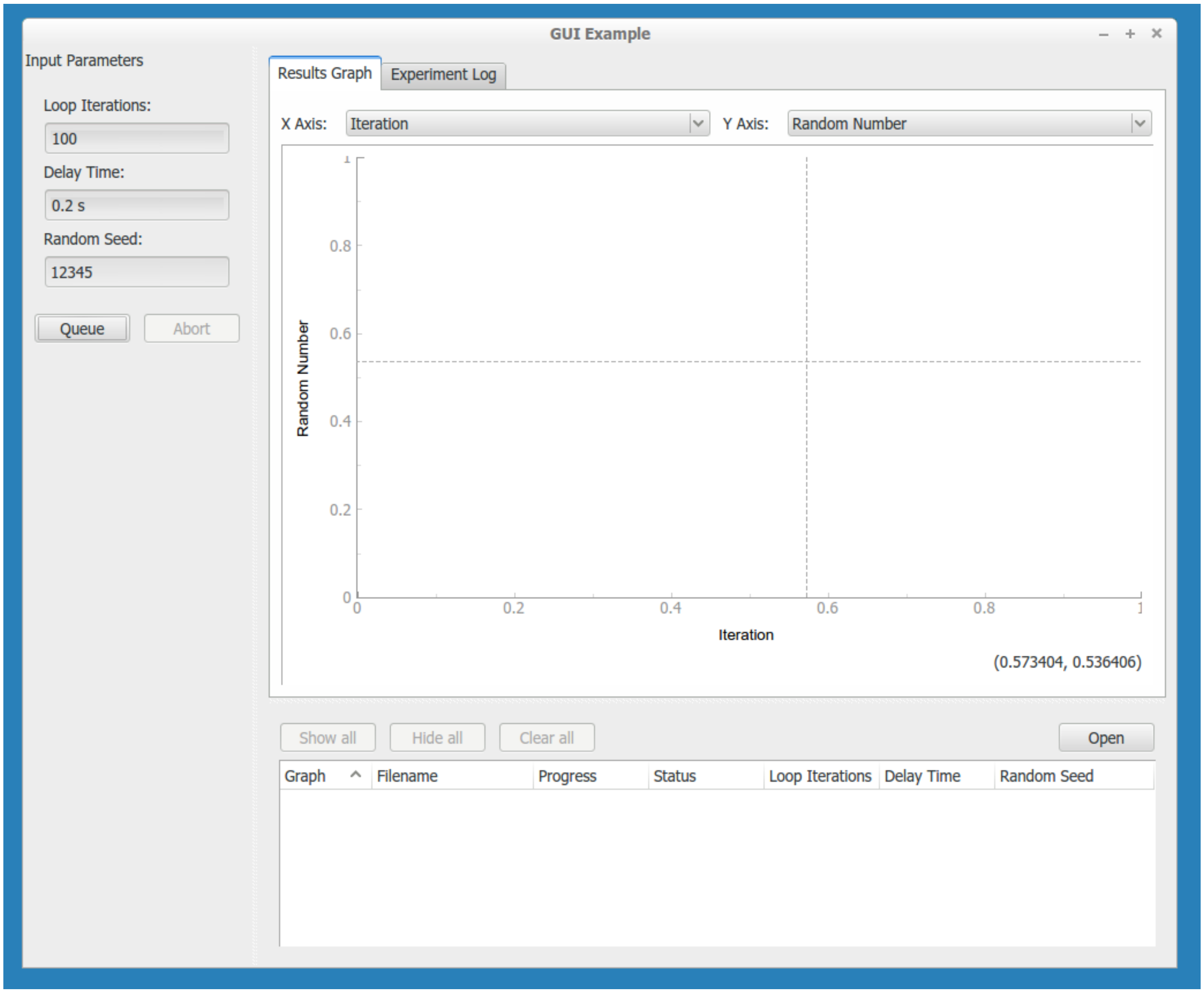
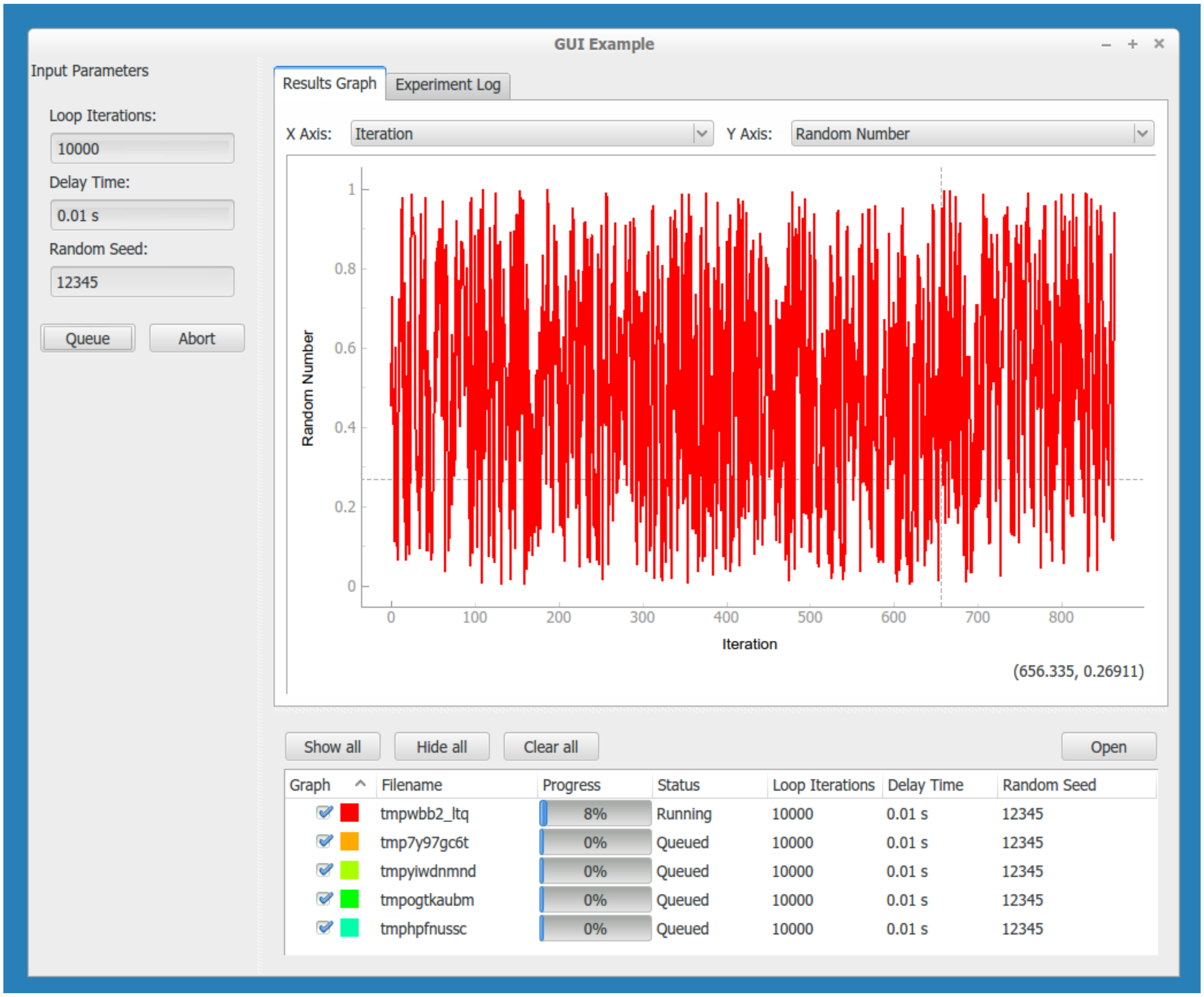
```
class MainWindow(ManagedWindow):

    def __init__(self):
        super().__init__(
            procedure_class=RandomProcedure,
            inputs=['iterations', 'delay', 'seed'],
            displays=['iterations', 'delay', 'seed'],
            x_axis='Iteration',
            y_axis='Random Number'
        )
        self.setWindowTitle('GUI Example')

    def queue(self):
        filename = tempfile.mktemp()

        procedure = self.make_procedure()
        results = Results(procedure, filename)
        experiment = self.new_experiment(results)

        self.manager.queue(experiment)


if __name__ == "__main__":
    app = QtGui.QApplication(sys.argv)
    window = MainWindow()
    window.show()
    sys.exit(app.exec_())
```

This results in the following graphical display.

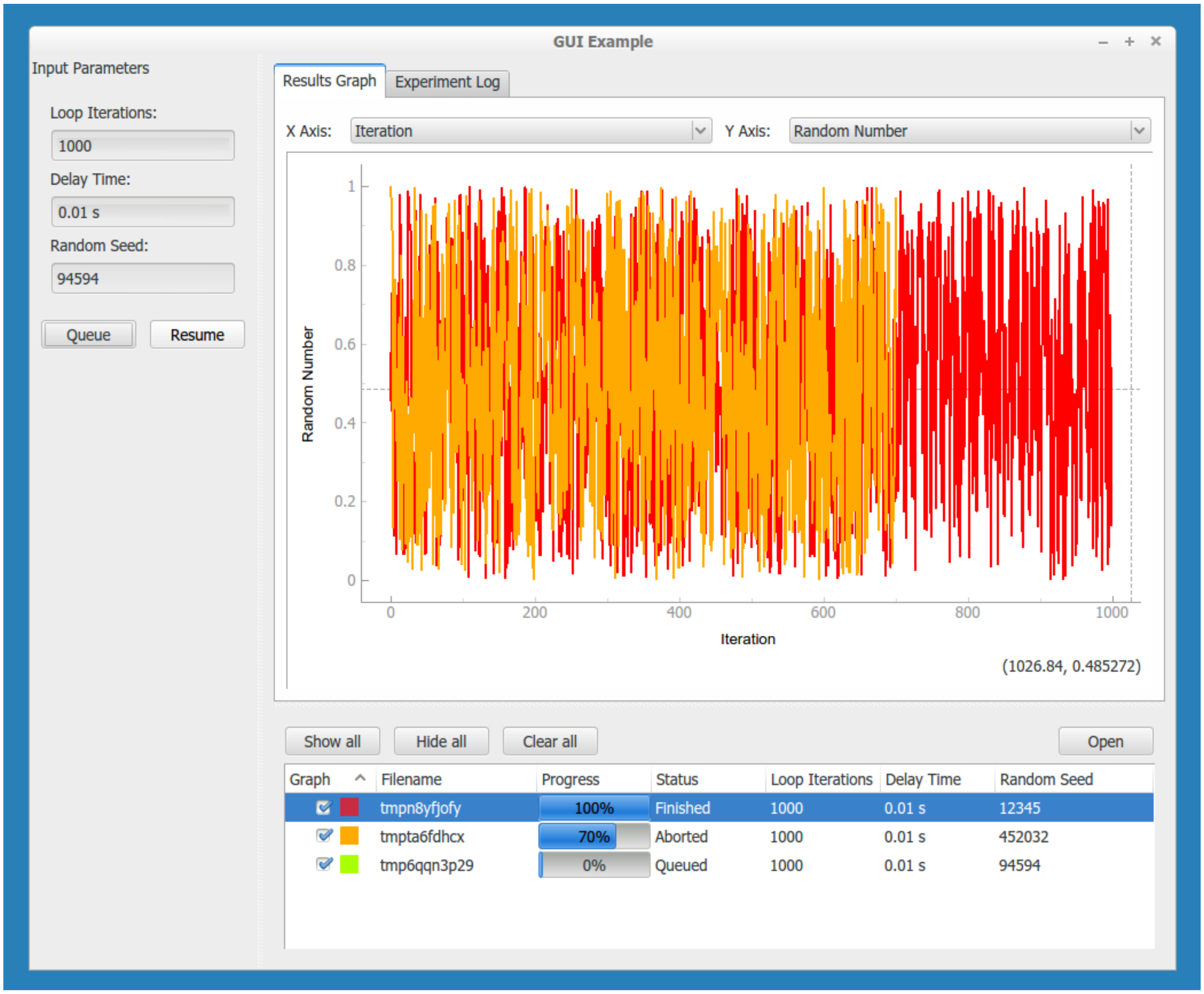



In the code, the MainWindow class is a sub-class of the ManagedWindow class. We override the constructor to provide information about the procedure class and its options. The `inputs` are a list of Parameters class-variable names, which the display will generate graphical fields for. When the list of inputs is long, a boolean key-word argument `inputs_in_scrollarea` is provided that adds a scrollbar to the input area. The `displays` is a list similar to the `inputs` list, which instead defines the parameters to display in the browser window. This browser keeps track of the experiments being run in the sequential queue.

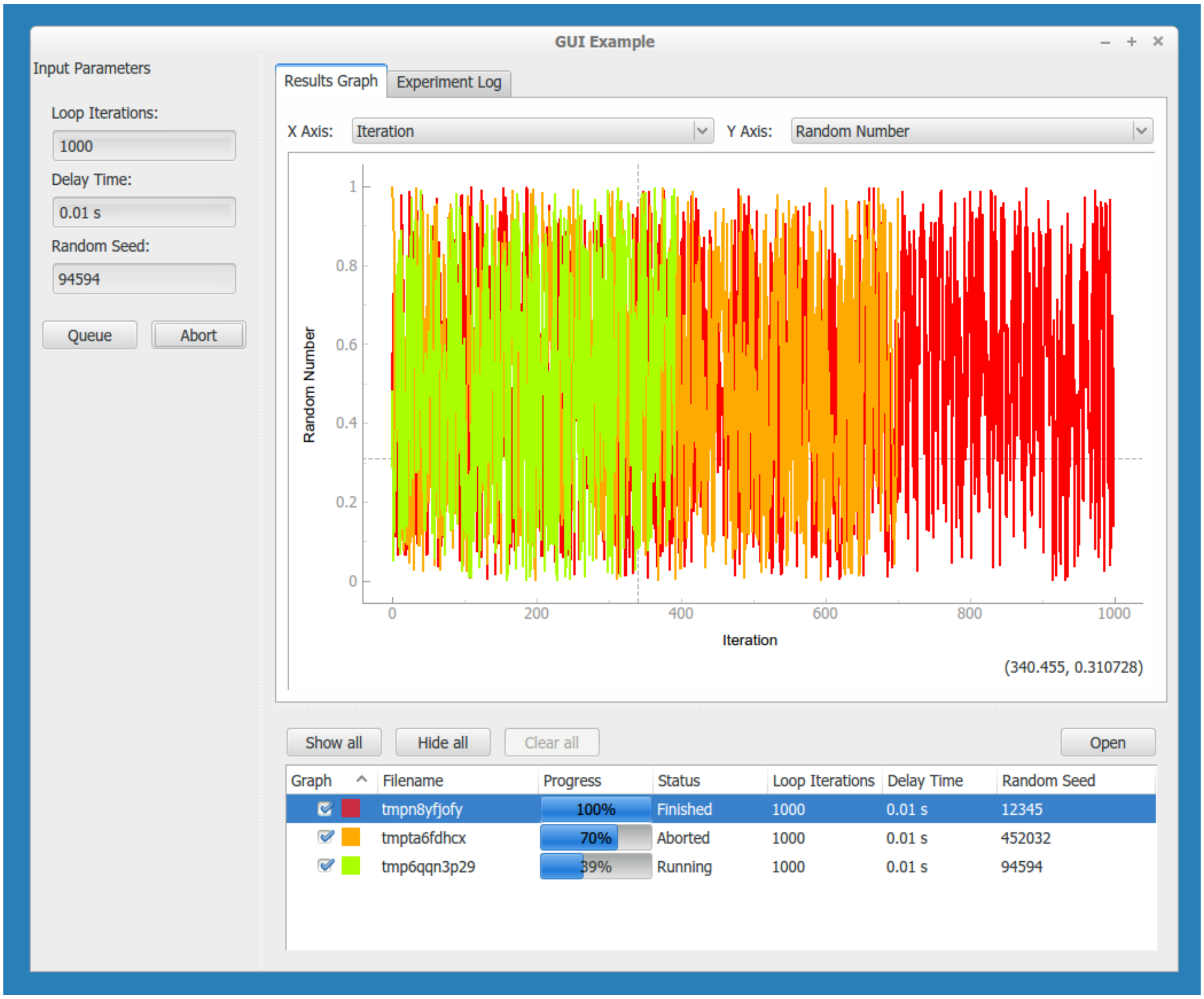
The `queue` method establishes how the Procedure object is constructed. We use the `self.make_procedure` method to create a Procedure based on the graphical input fields. Here we are free to modify the procedure before putting it on the queue. In this context, the Manager uses an Experiment object to keep track of the Procedure, Results, and its associated graphical representations in the browser and live-graph. This is then given to the Manager to queue the experiment.




By default the Manager starts a measurement when its procedure is queued. The abort button can be pressed to stop an experiment. In the Procedure, the `self.should_stop` call will catch the abort event and halt the measurement. It is important to check this value, or the Procedure will not be responsive to the abort event.




If you abort a measurement, the resume button must be pressed to continue the next measurement. This allows you to adjust anything, which is presumably why the abort was needed.




Now that you have learned about the ManagedWindow, you have all of the basics to get up and running quickly with a measurement and produce an easy to use graphical interface with PyMeasure.

**Note:** For performance reasons, the default linewidth of all the graphs has been set to 1. If performance is not an issue, the linewidth can be changed to 2 (or any other value) for better visibility by using the *linewidth* keyword-argument in the *Plotter* or the *ManagedWindow*. Whenever a linewidth of 2 is prefered and a better performance is required, it is possible to enable using OpenGL in the import section of the file:

```
import pyqtgraph as pg
pg.setConfigOption("useOpenGL", True)
```

### 3.3.3 Customising the plot options

For both the PlotterWindow and ManagedWindow, plotting is provided by the pyqtgraph library. This library allows you to change various plot options, as you might expect: axis ranges (by default auto-ranging), logarithmic and semilogarithmic axes, downsampling, grid display, FFT display, etc. There are two main ways you can do this:

1. You can right click on the plot to manually change any available options. This is also a good way of getting an overview of what options are available in pyqtgraph. Option changes will, of course, not persist across a restart of your program.
2. You can programmatically set these options using pyqtgraph's PlotItem API, so that the window will open with these display options already set, as further explained below.

For *Plotter*, you can make a sub-class that overrides the *setup_plot()* method. This method will be called when the Plotter constructs the window. As an example

```
class LogPlotter(Plotter):
    def setup_plot(self, plot):
        # use logarithmic x-axis (e.g. for frequency sweeps)
        plot.setLogMode(x=True)
```

For *ManagedWindow*, the mechanism to customize plots is much more flexible by using specialization via inheritance. Indeed *ManagedWindowBase* is the base class for *ManagedWindow* and *ManagedImageWindow* which are subclasses ready to use for GUI.

### 3.3.4 Defining your own ManagedWindow's widgets

The parameter `widget_list` in *ManagedWindowBase* constructor allow to introduce user's defined widget in the GUI results display area. The user's widget should inherit from `TabWidget` and could reimplement any of the methods that needs customization. In order to get familiar with the mechanism, users can check the following widgets already provided:

- `LogWidget`
- `PlotWidget`
- `ImageWidget`

### 3.3.5 Using the sequencer

As an extension to the way of graphically inputting parameters and executing multiple measurements using the *ManagedWindow*, `SequencerWidget` is provided which allows users to queue a series of measurements with varying one, or more, of the parameters. This sequencer thereby provides a convenient way to scan through the parameter space of the measurement procedure.

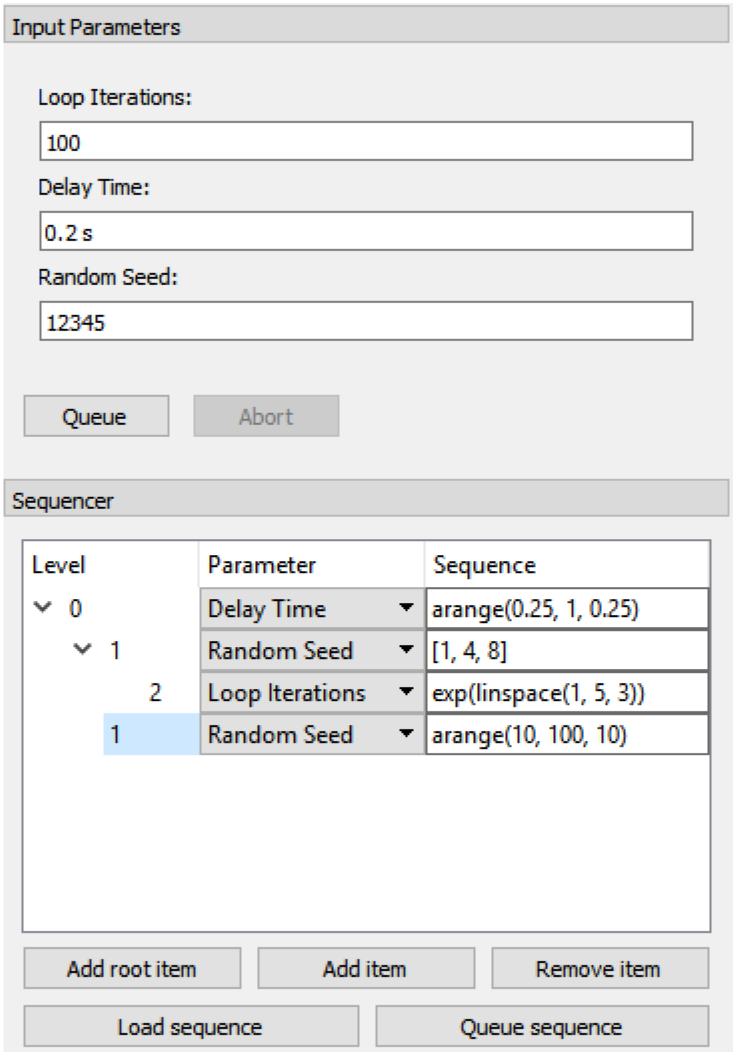
To activate the sequencer, two additional keyword arguments are added to *ManagedWindow*, namely `sequencer` and `sequencer_inputs`. `sequencer` accepts a boolean stating whether or not the sequencer has to be included into the window and `sequencer_inputs` accepts either `None` or a list of the parameter names are to be scanned over. If no list of parameters is given, the parameters displayed in the manager queue are used.

In order to be able to use the sequencer, the *ManagedWindow* class is required to have a `queue` method which takes a keyword (or better keyword-only for safety reasons) argument `procedure`, where a procedure instance can be passed. The sequencer will use this method to queue the parameter scan.

In order to implement the sequencer into the previous example, only the `MainWindow` has to be modified slightly (where modified lines are marked):

```python
class MainWindow(ManagedWindow):

    def __init__(self):
        super().__init__(
            procedure_class=TestProcedure,
            inputs=['iterations', 'delay', 'seed'],
            displays=['iterations', 'delay', 'seed'],
            x_axis='Iteration',
            y_axis='Random Number',
            sequencer=True,                                       # Added line
            sequencer_inputs=['iterations', 'delay', 'seed'],    # Added line
            sequence_file="gui_sequencer_example_sequence.txt",  # Added line, optional
        )
        self.setWindowTitle('GUI Example')

    def queue(self, procedure=None):                              # Modified line
        filename = tempfile.mktemp()

        if procedure is None:                                     # Added line
            procedure = self.make_procedure()                     # Indented

        results = Results(procedure, filename)
        experiment = self.new_experiment(results)

        self.manager.queue(experiment)
```

This adds the sequencer underneath the the input panel.




The widget contains a tree-view where you can build the sequence. It has three columns: `level` (indicated how deep an item is nested), `parameter` (a drop-down menu to select which parameter is being sequenced by that item), and `sequence` (the text-box where you can define the sequence). While the two former columns are rather straightforward, filling in the later requires some explanation.

In order to maintain flexibility, the sequence is defined in a text-box, allowing the user to enter any list-generating single-line piece of code. To assist in this, a number of functions is supported, either from the main python library (namely `range`, `sorted`, and `list`) or the numpy library. The supported numpy functions (prepending `numpy.` or any abbreviation is not required) are: `arange`, `linspace`, `arccos`, `arcsin`, `arctan`, `arctan2`, `ceil`, `cos`, `cosh`, `degrees`, `e`, `exp`, `fabs`, `floor`, `fmod`, `frexp`, `hypot`, `ldexp`, `log`, `log10`, `modf`, `pi`, `power`, `radians`, `sin`, `sinh`, `sqrt`, `tan`, and `tanh`.

As an example, `arange(0, 10, 1)` generates a list increasing with steps of 1, while using `exp(arange(0, 10, 1))` generates an exponentially increasing list. This way complex sequences can be entered easily.

The sequences can be extended and shortened using the buttons `Add root item`, `Add item`, and `Remove item`. The later two either add a item as a child of the currently selected item or remove the selected item, respectively. To queue the entered sequence the button `Queue` sequence can be used. If an error occurs in evaluating the sequence text-boxes, this is mentioned in the logger, and nothing is queued.

Finally, it is possible to write a simple text file to quickly load a pre-defined sequence with the `Load sequence` button, such that the user does not need to write the sequence again each time. In the sequence file each line adds one item to the sequence tree, starting with a number of dashes (-) to indicate the level of the item (starting with 1 dash for top level), followed by the name of the parameter and the sequence string, both as a python string between parentheses. An example of such a sequence file is given below, resulting in the sequence shown in the figure above.

```
- "Delay Time", "arange(0.25, 1, 0.25)"
-- "Random Seed", "[1, 4, 8]"
--- "Loop Iterations", "exp(linspace(1, 5, 3))"
-- "Random Seed", "arange(10, 100, 10)"
```

This file can also be automatically loaded at the start of the program by adding the key-word argument `sequence_file="filename.txt"` to the `super().__init__` call, as was done in the example.

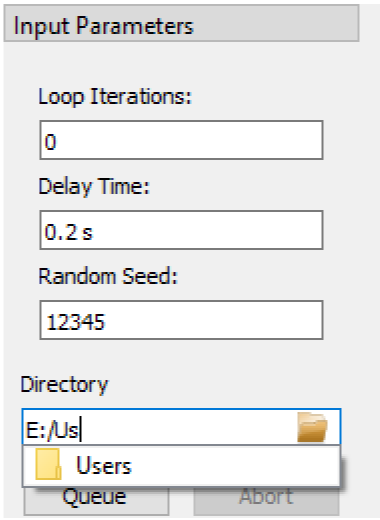
### 3.3.6 Using the directory input

It is possible to add a directory input in order to choose where the experiment's result will be saved. This option is activated by passing a boolean key-word argument `directory_input` during the *ManagedWindow* init. The value of the directory can be retrieved and set using the property `directory`. A default directory can be defined by setting the `directory` property in the MainWindow init.

Only the MainWindow needs to be modified in order to use this option (modified lines are marked).

```python
class MainWindow(ManagedWindow):

    def __init__(self):
        super().__init__(
            procedure_class=TestProcedure,
            inputs=['iterations', 'delay', 'seed'],
            displays=['iterations', 'delay', 'seed'],
            x_axis='Iteration',
            y_axis='Random Number',
            directory_input=True,                               # Added line, enables␣
↪directory widget
        )
        self.setWindowTitle('GUI Example')
        self.directory = r'C:/Path/to/default/directory'       # Added line, sets␣
↪default directory for GUI load

    def queue(self):
        directory = self.directory                              # Added line
        filename = unique_filename(directory)                   # Modified line

        results = Results(procedure, filename)
        experiment = self.new_experiment(results)

        self.manager.queue(experiment)
```

This adds the input line above the Queue and Abort buttons.




A completer is implemented allowing to quickly select an existing folder, and a button on the right side of the input widget opens a browse dialog.

### 3.3.7 Using the estimator widget

In order to provide estimates of the measurement procedure, an `EstimatorWidget` is provided that allows the user to define and calculate estimates. The widget is automatically activated when the `get_estimates` method is added in the `Procedure`.

The quickest and most simple implementation of the `get_estimates` function simply returns the estimated duration of the measurement in seconds (as an `int` or a `float`). As an example, in the example provided in the *Using the ManagedWindow* section, the `Procedure` is changed to:

```
class RandomProcedure(Procedure):

    # ...

    def get_estimates(self, sequence_length=None, sequence=None):

        return self.iterations * self.delay
```

This will add the estimator widget at the dock on the left. The duration and finishing-time of a single measurement is always displayed in this case. Depending on whether the SequencerWidget is also used, the length, duration and finishing-time of the full sequence is also shown.

For maximum flexibility (e.g. for showing multiple and other types of estimates, such as the duration, filesize, finishing-time, etc.) it is also possible that the `get_estimates` returns a list of tuples. Each of these tuple consists of two strings: the first is the name (label) of the estimate, the second is the estimate itself.

As an example, in the example provided in the *Using the ManagedWindow* section, the `Procedure` is changed to:

```
class RandomProcedure(Procedure):

    # ...

    def get_estimates(self, sequence_length=None, sequence=None):
```

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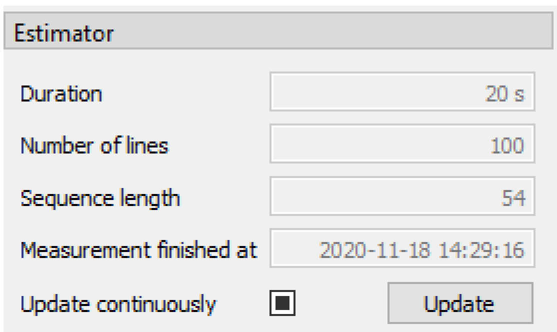
```
        duration = self.iterations * self.delay

        estimates = [
            ("Duration", "%d s" % int(duration)),
            ("Number of lines", "%d" % int(self.iterations)),
            ("Sequence length", str(sequence_length)),
            ('Measurement finished at', str(datetime.now() + timedelta(seconds=duration))),
        ]

        return estimates
```

This will add the estimator widget at the dock on the left.




Note that after the initialisation of the widget both the label of the estimate as of course the estimate itself can be modified, but the amount of estimates is fixed.

The keyword arguments are not required in the implementation of the function, but are passed if asked for (i.e. `def get_estimates(self)` does also works). Keyword arguments that are accepted are `sequence`, which contains the full sequence of the sequencer (if present), and `sequence_length`, which gives the length of the sequence as integer (if present). If the sequencer is not present or the sequence cannot be parsed, both `sequence` and `sequence_length` will contain `None`.

The estimates are automatically updated every 2 seconds. Changing this update interval is possible using the "Update continuously"-checkbox, which can be toggled between three states: off (i.e. no updating), auto-update every two seconds (default) or auto-update every 100 milliseconds. Manually updating the estimates (useful whenever continuous updating is turned off) is also possible using the "update"-button.

### 3.3.8 Flexible hiding of inputs

There can be situations when it may be relevant to turn on or off a number of inputs (e.g. when a part of the measurement script is skipped upon turning of a single `BooleanParameter`). For these cases, it is possible to assign a `Parameter` to a controlling `Parameter`, which will hide or show the `Input` of the `Parameter` depending on the value of the `Parameter`. This is done with the `group_by` key-word argument.

```
toggle = BooleanParameter("toggle", default=True)
param = FloatParameter('some parameter', group_by='toggle')
```

When both the `toggle` and `param` are visible in the `InputsWidget` (via `inputs=['iterations', 'delay', 'seed']` as demonstrated above) one can control whether the input-field of `param` is visible by checking and unchecking the checkbox of `toggle`. By default, the group will be visible if the value of the `group_by` `Parameter` is `True` (which is only relevant for a `BooleanParameter`), but it is possible to specify other value as conditions using the `group_condition` keyword argument.

```
iterations = IntegerParameter('Loop Iterations', default=100)
param = FloatParameter('some parameter', group_by='iterations', group_condition=99)
```

Here the input of `param` is only visible if `iterations` has a value of 99. This works with any type of `Parameter` as `group_by` parameter.

To allow for even more flexibility, it is also possible to pass a (lambda)function as a condition:

```
iterations = IntegerParameter('Loop Iterations', default=100)
param = FloatParameter('some parameter', group_by='iterations', group_condition=lambda v: 50 < v < 100)
```

Now the input of `param` is only shown if the value of `iterations` is between 51 and 99.

Using the `hide_groups` keyword-argument of the `ManagedWindow` you can choose between hiding the groups (`hide_groups = True`) and disabling / graying-out the groups (`hide_groups = False`).

Finally, it is also possible to provide multiple parameters to the `group_by` argument, in which case the input will only be visible if all of the conditions are true. Multiple parameters for grouping can either be passed as a dict of string: condition pairs, or as a list of strings, in which case the `group_condition` can be either a single condition or a list of conditions:

```
iterations = IntegerParameter('Loop Iterations', default=100)
toggle = BooleanParameter('A checkbox')
param_A = FloatParameter('some parameter', group_by=['iterations', 'toggle'], group_condition=[lambda v: 50 < v < 100, True])
param_B = FloatParameter('some parameter', group_by={'iterations': lambda v: 50 < v < 100, 'toggle': True})
```

Note that in this example, `param_A` and `param_B` are identically grouped: they're only visible if `iterations` is between 51 and 99 and if the *toggle* checkbox is checked (i.e. True).

CHAPTER

FOUR

# PYMEASURE.ADAPTERS

The adapter classes allow the instruments to be independent of the communication method used.

Adapters for specific instruments should be grouped in an `adapters.py` file in the corresponding manufacturer's folder of `pymeasure.instruments`. For example, the adapter for communicating with LakeShore instruments over USB, *LakeShoreUSBAdapter*, is found in `pymeasure.instruments.lakeshore.adapters`.

## 4.1 Adapter base class

**class** `pymeasure.adapters.Adapter`(*preprocess_reply=None*, ***kwargs*)

Base class for Adapter child classes, which adapt between the Instrument object and the connection, to allow flexible use of different connection techniques.

This class should only be inherited from.

**Parameters**

- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **kwargs** – all other keyword arguments are ignored.

**ask**(*command*)

Writes the command to the instrument and returns the resulting ASCII response

**Parameters** **command** – SCPI command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)

Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()

Reads until the buffer is empty and returns the resulting ASCII respone

**Returns** String ASCII response of the instrument.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)

Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)

Writes a command to the instrument

**Parameters** **command** – SCPI command string to be sent to the instrument

## 4.2 VISA adapter

**class** pymeasure.adapters.**VISAAdapter**(*resource_name*, *visa_library=''*, *preprocess_reply=None*, ***kwargs*)

Bases: *pymeasure.adapters.adapter.Adapter*

Adapter class for the VISA library, using PyVISA to communicate with instruments.

The workhorse of our library, used by most instruments.

**Parameters**

- **resource_name** – A VISA resource string or GPIB address integer that identifies the target of the connection
- **visa_library** – PyVISA VisaLibrary Instance, path of the VISA library or VisaLibrary spec string (`@py` or `@ivi`). If not given, the default for the platform will be used.
- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- ****kwargs** – Keyword arguments for configuring the PyVISA connection.

**Kwargs** Keyword arguments are used to configure the connection created by PyVISA. This is complicated by the fact that *which* arguments are valid depends on the interface (e.g. serial, GPIB, TCPI/IP, USB) determined by the current `resource_name`.

A flexible process is used to easily define reasonable *default values* for different instrument interfaces, but also enable the instrument user to *override any setting* if their situation demands it.

A kwarg that names a pyVISA interface type (most commonly `asrl`, `gpib`, `tcpip` or `usb`) is a dictionary with keyword arguments defining defaults specific to that interface. Example: `asrl={'baud_rate': 4200}`.

All other kwargs are either generally valid (e.g. `timeout=500`) or override any default settings from the interface-specific entries above. For example, passing `baud_rate=115200` when connecting via a resource name `ASRL1` would override a default of 4200 defined as above.

See *Modifying connection settings* for how to tweak settings when *connecting* to an instrument. See *Defining default connection settings* for how to best define default settings when *implementing an instrument*.

`ask(command)`
Writes the command to the instrument and returns the resulting ASCII response

**Parameters** `command` – SCPI command string to be sent to the instrument

**Returns** String ASCII response of the instrument

`ask_values(command, **kwargs)`
Writes a command to the instrument and returns a list of formatted values from the result. This leverages the *query_ascii_values* method in PyVISA.

**Parameters**

- `command` – SCPI command to be sent to the instrument
- `kwargs` – Key-word arguments to pass onto *query_ascii_values*

**Returns** Formatted response of the instrument.

`binary_values(command, header_bytes=0, dtype=<class 'numpy.float32'>)`
Returns a numpy array from a query for binary data

**Parameters**

- `command` – SCPI command to be sent to the instrument
- `header_bytes` – Integer number of bytes to ignore in header
- `dtype` – The NumPy data type to format the values with

**Returns** NumPy array of values

`flush_read_buffer()`
Flush and discard the input buffer

As detailed by pyvisa, discard the read buffer contents and if data was present in the read buffer and no END-indicator was present, read from the device until encountering an END indicator (which causes loss of data).

`static has_supported_version()`
Returns True if the PyVISA version is greater than 1.8

`read()`
Reads until the buffer is empty and returns the resulting ASCII response

**Returns** String ASCII response of the instrument.

`read_bytes(size)`
Reads specified number of bytes from the buffer and returns the resulting ASCII response

**Parameters** `size` – Number of bytes to read from the buffer

**Returns** String ASCII response of the instrument.

`values(command, separator=', ', cast=<class 'float'>, preprocess_reply=None)`
Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- `command` – SCPI command to be sent to the instrument
- `separator` – A separator character to split the string into a list
- `cast` – A type to cast the result

- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**wait_for_srq**(*timeout=25*, *delay=0.1*)
Blocks until a SRQ, and leaves the bit high

**Parameters**

- **timeout** – Timeout duration in seconds
- **delay** – Time delay between checking SRQ in seconds

**write**(*command*)
Writes a command to the instrument

**Parameters** **command** – SCPI command string to be sent to the instrument

**write_binary_values**(*command*, *values*, ***kwargs*)
Write binary data to the instrument, e.g. waveform for signal generators

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **values** – iterable representing the binary values
- **kwargs** – Key-word arguments to pass onto *write_binary_values*

**Returns** number of bytes written

## 4.3 Serial adapter

class pymeasure.adapters.**SerialAdapter**(*port*, *preprocess_reply=None*, ***kwargs*)
Bases: `pymeasure.adapters.adapter.Adapter`

Adapter class for using the Python Serial package to allow serial communication to instrument

**Parameters**

- **port** – Serial port
- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **kwargs** – Any valid key-word argument for serial.Serial

**_format_binary_values**(*values*, *datatype='f'*, *is_big_endian=False*, *header_fmt='ieee'*)
Format values in binary format, used internally in `write_binary_values()`.

**Parameters**

- **values** – data to be written to the device.
- **datatype** – the format string for a single element. See struct module.
- **is_big_endian** – boolean indicating endianess.
- **header_fmt** – Format of the header prefixing the data ("ieee", "hp", "empty").

**Returns** binary string.

**Return type** bytes

**ask**(*command*)
Writes the command to the instrument and returns the resulting ASCII response

**Parameters** **command** – SCPI command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)
Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()
Reads until the buffer is empty and returns the resulting ASCII response

**Returns** String ASCII response of the instrument.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)
Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)
Writes a command to the instrument

**Parameters** **command** – SCPI command string to be sent to the instrument

**write_binary_values**(*command*, *values*, ***kwargs*)
Write binary data to the instrument, e.g. waveform for signal generators

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **values** – iterable representing the binary values
- **kwargs** – Key-word arguments to pass onto `_format_binary_values()`

**Returns** number of bytes written

## 4.4 Prologix adapter

**class** pymeasure.adapters.**PrologixAdapter**(*port*, *address=None*, *rw_delay=None*, *serial_timeout=0.5*, *preprocess_reply=None*, ***kwargs*)

Bases: `pymeasure.adapters.serial.SerialAdapter`

Encapsulates the additional commands necessary to communicate over a Prologix GPIB-USB Adapter, using the SerialAdapter.

Each PrologixAdapter is constructed based on a serial port or connection and the GPIB address to be communicated to. Serial connection sharing is achieved by using the `gpib()` method to spawn new PrologixAdapters for different GPIB addresses.

**Parameters**

- **port** – The Serial port name or a serial.Serial object
- **address** – Integer GPIB address of the desired instrument
- **rw_delay** – An optional delay to set between a write and read call for slow to respond instruments.
- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **kwargs** – Key-word arguments if constructing a new serial object

**Variables** **address** – Integer GPIB address of the desired instrument

To allow user access to the Prologix adapter in Linux, create the file: `/etc/udev/rules.d/51-prologix.rules`, with contents:

```
SUBSYSTEMS=="usb",ATTRS{idVendor}=="0403",ATTRS{idProduct}=="6001",MODE="0666"
```

Then reload the udev rules with:

```
sudo udevadm control --reload-rules
sudo udevadm trigger
```

**_format_binary_values**(*values*, *datatype='f'*, *is_big_endian=False*, *header_fmt='ieee'*)

Format values in binary format, used internally in `write_binary_values()`.

**Parameters**

- **values** – data to be writen to the device.
- **datatype** – the format string for a single element. See struct module.
- **is_big_endian** – boolean indicating endianess.
- **header_fmt** – Format of the header prefixing the data (“ieee”, “hp”, “empty”).

**Returns** binary string.

**Return type** bytes

**ask**(*command*)

Ask the Prologix controller, include a forced delay for some instruments.

**Parameters** **command** – SCPI command string to be sent to instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)

Returns a numpy array from a query for binary data

**Parameters**

- `command` – SCPI command to be sent to the instrument
- `header_bytes` – Integer number of bytes to ignore in header
- `dtype` – The NumPy data type to format the values with

**Returns** NumPy array of values

`gpib`(*address*, *rw_delay=None*)

Returns and PrologixAdapter object that references the GPIB address specified, while sharing the Serial connection with other calls of this function

**Parameters**

- `address` – Integer GPIB address of the desired instrument
- `rw_delay` – Set a custom Read/Write delay for the instrument

**Returns** PrologixAdapter for specific GPIB address

`read`()

Reads the response of the instrument until timeout

**Returns** String ASCII response of the instrument

`set_defaults`()

Sets up the default behavior of the Prologix-GPIB adapter

`values`(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)

Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- `command` – SCPI command to be sent to the instrument
- `separator` – A separator character to split the string into a list
- `cast` – A type to cast the result
- `preprocess_reply` – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

`wait_for_srq`(*timeout=25*, *delay=0.1*)

Blocks until a SRQ, and leaves the bit high

**Parameters**

- `timeout` – Timeout duration in seconds
- `delay` – Time delay between checking SRQ in seconds

`write`(*command*)

Writes the command to the GPIB address stored in the `address`

**Parameters** `command` – SCPI command string to be sent to the instrument

`write_binary_values`(*command*, *values*, ***kwargs*)

Write binary data to the instrument, e.g. waveform for signal generators.

values are encoded in a binary format according to IEEE 488.2 Definite Length Arbitrary Block Response Data block.

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **values** – iterable representing the binary values
- **kwargs** – Key-word arguments to pass onto `_format_binary_values()`

**Returns** number of bytes written

## 4.5 VXI-11 adapter

**class** pymeasure.adapters.**VXI11Adapter**(*host*, *preprocess_reply=None*, ***kwargs*)

Bases: `pymeasure.adapters.adapter.Adapter`

**VXI11 Adapter class. Provides a adapter object that** wraps around the read, write and ask functionality of the vxi11 library.

**Parameters**

- **host** – string containing the visa connection information.
- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.

**ask**(*command*)

Wrapper function for the ask command using the vx11 interface.

**Parameters** **command** – string with the command that will be transmitted to the instrument.

:returns string containing a response from the device.

**ask_raw**(*command*)

Wrapper function for the ask_raw command using the vx11 interface.

**Parameters** **command** – binary string with the command that will be transmitted to the instrument

:returns binary string containing the response from the device.

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)

Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()

Wrapper function for the read command using the vx11 interface.

:return string containing a response from the device.

**read_raw**()

Wrapper function for the read_raw command using the vx11 interface.

:returns binary string containing the response from the device.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)

Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)
Wrapper function for the write command using the vxi11 interface.

**Parameters** **command** – string with command the that will be transmitted to the instrument.

**write_raw**(*command*)
Wrapper function for the write_raw command using the vxi11 interface.

**Parameters** **command** – binary string with the command that will be transmitted to the instrument

## 4.6 Telnet adapter

**class** pymeasure.adapters.**TelnetAdapter**(*host*, *port=0*, *query_delay=0*, *preprocess_reply=None*, ***kwargs*)
Bases: `pymeasure.adapters.adapter.Adapter`

Adapter class for using the Python telnetlib package to allow communication to instruments

**Parameters**

- **host** – host address of the instrument
- **port** – TCPIP port
- **query_delay** – delay in seconds between write and read in the ask method
- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **kwargs** – Valid keyword arguments for telnetlib.Telnet, currently this is only 'timeout'

**ask**(*command*)
Writes a command to the instrument and returns the resulting ASCII response

**Parameters** **command** – command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)
Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()
Read something even with blocking the I/O. After something is received check again to obtain a full reply.

**Returns** String ASCII response of the instrument.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)
Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)
Writes a command to the instrument

**Parameters** **command** – command string to be sent to the instrument

## 4.7 Fake adapter

**class** pymeasure.adapters.**FakeAdapter**(*preprocess_reply=None*, ***kwargs*)
Bases: *pymeasure.adapters.adapter.Adapter*

Provides a fake adapter for debugging purposes, which bounces back the command so that arbitrary values testing is possible.

```
a = FakeAdapter()
assert a.read() == ""
a.write("5")
assert a.read() == "5"
assert a.read() == ""
assert a.ask("10") == "10"
assert a.values("10") == [10]
```

**ask**(*command*)
Writes the command to the instrument and returns the resulting ASCII response

**Parameters** **command** – SCPI command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)
Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()
Returns the last commands given after the last read call.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)

Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)

Writes the command to a buffer, so that it can be read back.

CHAPTER

FIVE

# PYMEASURE.EXPERIMENT

This section contains specific documentation on the classes and methods of the package.

## 5.1 Experiment class

The Experiment class is intended for use in the Jupyter notebook environment.

**class** pymeasure.experiment.experiment.**Experiment**(*title*, *procedure*, *analyse=<function Experiment.<lambda>>*)

Bases: object

Class which starts logging and creates/runs the results and worker processes.

```
procedure = Procedure()
experiment = Experiment(title, procedure)
experiment.start()
experiment.plot_live('x', 'y', style='.-')

for a multi-subplot graph:

import pylab as pl
ax1 = pl.subplot(121)
experiment.plot('x','y',ax=ax1)
ax2 = pl.subplot(122)
experiment.plot('x','z',ax=ax2)
experiment.plot_live()
```

**Variables** **value** – The value of the parameter

**Parameters**

- **title** – The experiment title
- **procedure** – The procedure object
- **analyse** – Post-analysis function, which takes a pandas dataframe as input and returns it with added (analysed) columns. The analysed results are accessible via experiment.data, as opposed to experiment.results.data for the 'raw' data.
- **_data_timeout** – Time limit for how long live plotting should wait for datapoints.

**clear_plot**()

Clear the figures and plot lists.

**property data**
Data property which returns analysed data, if an analyse function is defined, otherwise returns the raw data.

**plot**(**args*, ***kwargs*)
Plot the results from the experiment.data pandas dataframe. Store the plots in a plots list attribute.

**plot_live**(**args*, ***kwargs*)
Live plotting loop for jupyter notebook, which automatically updates (an) in-line matplotlib graph(s). Will create a new plot as specified by input arguments, or will update (an) existing plot(s).

**start**()
Start the worker

**update_line**(*ax*, *hl*, *xname*, *yname*)
Update a line in a matplotlib graph with new data.

**update_plot**()
Update the plots in the plots list with new data from the experiment.data pandas dataframe.

**wait_for_data**()
Wait for the data attribute to fill with datapoints.

pymeasure.experiment.experiment.**create_filename**(*title*)
Create a new filename according to the style defined in the config file. If no config is specified, create a temporary file.

pymeasure.experiment.experiment.**get_array**(*start*, *stop*, *step*)
Returns a numpy array from start to stop

pymeasure.experiment.experiment.**get_array_steps**(*start*, *stop*, *numsteps*)
Returns a numpy array from start to stop in numsteps

pymeasure.experiment.experiment.**get_array_zero**(*maxval*, *step*)
Returns a numpy array from 0 to maxval to -maxval to 0

## 5.2 Listener class

class pymeasure.experiment.listeners.**Listener**(*port*, *topic=''*, *timeout=0.01*)
Bases: `pymeasure.thread.StoppableThread`

Base class for Threads that need to listen for messages on a ZMQ TCP port and can be stopped by a thread-safe method call

**message_waiting**()
Check if we have a message, wait at most until timeout.

**receive**(*flags=0*)

class pymeasure.experiment.listeners.**Monitor**(*results*, *queue*)
Bases: `pymeasure.log.QueueListener`

class pymeasure.experiment.listeners.**Recorder**(*results*, *queue*, ***kwargs*)
Bases: `pymeasure.log.QueueListener`

Recorder loads the initial Results for a filepath and appends data by listening for it over a queue. The queue ensures that no data is lost between the Recorder and Worker.

**stop**()
Stop the listener.

This asks the thread to terminate, and then waits for it to do so. Note that if you don't call this before your application exits, there may be some records still left on the queue, which won't be processed.

## 5.3 Procedure class

class pymeasure.experiment.procedure.**Procedure**(***kwargs*)

Provides the base class of a procedure to organize the experiment execution. Procedures should be run by Workers to ensure that asynchronous execution is properly managed.

```
procedure = Procedure()
results = Results(procedure, data_filename)
worker = Worker(results, port)
worker.start()
```

Inheriting classes should define the startup, execute, and shutdown methods as needed. The shutdown method is called even with a software exception or abort event during the execute method.

If keyword arguments are provided, they are added to the object as attributes.

**check_parameters**()

Raises an exception if any parameter is missing before calling the associated function. Ensures that each value can be set and got, which should cast it into the right format. Used as a decorator @check_parameters on the startup method

**execute**()

Preforms the commands needed for the measurement itself. During execution the shutdown method will always be run following this method. This includes when Exceptions are raised.

**gen_measurement**()

Create MEASURE and DATA_COLUMNS variables for get_datapoint method.

**get_estimates**()

Function that returns estimates that are to be displayed by the EstimatorWidget. Must be reimplemented by subclasses. Should return an int or float representing the duration in seconds, or a list with a tuple for each estimate. The tuple should consists of two strings: the first will be used as the label of the estimate, the second as the displayed estimate.

**parameter_objects**()

Returns a dictionary of all the Parameter objects and grabs any current values that are not in the default definitions

**parameter_values**()

Returns a dictionary of all the Parameter values and grabs any current values that are not in the default definitions

**parameters_are_set**()

Returns True if all parameters are set

**refresh_parameters**()

Enforces that all the parameters are re-cast and updated in the meta dictionary

**set_parameters**(*parameters*, *except_missing=True*)

Sets a dictionary of parameters and raises an exception if additional parameters are present if except_missing is True

**shutdown**()

Executes the commands necessary to shut down the instruments and leave them in a safe state. This method is always run at the end.

`startup()`
Executes the commands needed at the start-up of the measurement

`class pymeasure.experiment.procedure.UnknownProcedure(parameters)`
Handles the case when a `Procedure` object can not be imported during loading in the `Results` class

`startup()`
Executes the commands needed at the start-up of the measurement

## 5.4 Parameter classes

The parameter classes are used to define input variables for a `Procedure`. They each inherit from the `Parameter` base class.

`class pymeasure.experiment.parameters.BooleanParameter(name, default=None, ui_class=None, group_by=None, group_condition=True)`
`Parameter` sub-class that uses the boolean type to store the value.

**Variables** `value` – The boolean value of the parameter

**Parameters**

- `name` – The parameter name
- `default` – The default boolean value
- `ui_class` – A Qt class to use for the UI of this parameter

`class pymeasure.experiment.parameters.FloatParameter(name, units=None, minimum=- 1000000000.0, maximum=1000000000.0, decimals=15, **kwargs)`
`Parameter` sub-class that uses the floating point type to store the value.

**Variables** `value` – The floating point value of the parameter

**Parameters**

- `name` – The parameter name
- `units` – The units of measure for the parameter
- `minimum` – The minimum allowed value (default: -1e9)
- `maximum` – The maximum allowed value (default: 1e9)
- `decimals` – The number of decimals considered (default: 15)
- `default` – The default floating point value
- `ui_class` – A Qt class to use for the UI of this parameter

`class pymeasure.experiment.parameters.IntegerParameter(name, units=None, minimum=- 1000000000.0, maximum=1000000000.0, **kwargs)`
`Parameter` sub-class that uses the integer type to store the value.

**Variables** `value` – The integer value of the parameter

**Parameters**

- `name` – The parameter name
- `units` – The units of measure for the parameter

- **minimum** – The minimum allowed value (default: -1e9)
- **maximum** – The maximum allowed value (default: 1e9)
- **default** – The default integer value
- **ui_class** – A Qt class to use for the UI of this parameter

`class pymeasure.experiment.parameters.ListParameter(name, choices=None, units=None, **kwargs)`

Parameter sub-class that stores the value as a list. String representation of choices must be unique.

**Parameters**

- **name** – The parameter name
- **choices** – An explicit list of choices, which is disregarded if None
- **units** – The units of measure for the parameter
- **default** – The default value
- **ui_class** – A Qt class to use for the UI of this parameter

`property choices`

Returns an immutable iterable of choices, or None if not set.

`class pymeasure.experiment.parameters.Measurable(name, fget=None, units=None, measure=True, default=None, **kwargs)`

Encapsulates the information for a measurable experiment parameter with information about the name, fget function and units if supplied. The value property is called when the procedure retrieves a datapoint and calls the fget function. If no fget function is specified, the value property will return the latest set value of the parameter (or default if never set).

**Variables** **value** – The value of the parameter

**Parameters**

- **name** – The parameter name
- **fget** – The parameter fget function (e.g. an instrument parameter)
- **default** – The default value

`class pymeasure.experiment.parameters.Parameter(name, default=None, ui_class=None, group_by=None, group_condition=True)`

Encapsulates the information for an experiment parameter with information about the name, and units if supplied.

**Variables** **value** – The value of the parameter

**Parameters**

- **name** – The parameter name
- **default** – The default value
- **ui_class** – A Qt class to use for the UI of this parameter
- **group_by** – Defines the Parameter(s) that controls the visibility of the associated input; can be a string containting the Parameter name, a list of strings with multiple Parameter names, or a dict containing {"Parameter name": condition} pairs.
- **group_condition** – The condition for the group_by Parameter that controls the visibility of this parameter, provided as a value or a (lambda)function. If the group_by argument is provided as a list of strings, this argument can be either a single condition or a list of conditions. If the group_by argument is provided as a dict this argument is ignored.

`is_set()`
Returns True if the Parameter value is set

**class** `pymeasure.experiment.parameters.`**`PhysicalParameter`**(*name*, *uncertaintyType='absolute'*, ***kwargs*)
*VectorParameter* sub-class of 2 dimensions to store a value and its uncertainty.

**Variables** **`value`** – The value of the parameter as a list of 2 floating point numbers

**Parameters**

- **`name`** – The parameter name
- **`uncertainty_type`** – Type of uncertainty, 'absolute', 'relative' or 'percentage'
- **`units`** – The units of measure for the parameter
- **`default`** – The default value
- **`ui_class`** – A Qt class to use for the UI of this parameter

**class** `pymeasure.experiment.parameters.`**`VectorParameter`**(*name*, *length=3*, *units=None*, ***kwargs*)
*Parameter* sub-class that stores the value in a vector format.

**Variables** **`value`** – The value of the parameter as a list of floating point numbers

**Parameters**

- **`name`** – The parameter name
- **`length`** – The integer dimensions of the vector
- **`units`** – The units of measure for the parameter
- **`default`** – The default value
- **`ui_class`** – A Qt class to use for the UI of this parameter

## 5.5 Worker class

**class** `pymeasure.experiment.workers.`**`Worker`**(*results*, *log_queue=None*, *log_level=20*, *port=None*)
Bases: `pymeasure.thread.StoppableThread`

Worker runs the procedure and emits information about the procedure and its status over a ZMQ TCP port. In a child thread, a Recorder is run to write the results to

**`emit`**(*topic*, *record*)
Emits data of some topic over TCP

**`handle_abort`**()

**`handle_error`**()

**`join`**(*timeout=0*)
Joins the current thread and forces it to stop after the timeout if necessary

**Parameters** **`timeout`** – Timeout duration in seconds

**`run`**()
Method representing the thread's activity.

You may override this method in a subclass. The standard run() method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the args and kwargs arguments, respectively.

**shutdown**()

**update_status**(*status*)

## 5.6 Results class

class pymeasure.experiment.results.**CSVFormatter**(*columns*, *delimiter=','*)
Formatter of data results

**format**(*record*)
Formats a record as csv.

**Parameters** **record** (*dict*) – record to format.

**Returns** a string

class pymeasure.experiment.results.**Results**(*procedure*, *data_filename*)
The Results class provides a convenient interface to reading and writing data in connection with a *Procedure* object.

**Variables**

- **COMMENT** – The character used to identify a comment (default: #)
- **DELIMITER** – The character used to delimit the data (default: ,)
- **LINE_BREAK** – The character used for line breaks (default n)
- **CHUNK_SIZE** – The length of the data chuck that is read

**Parameters**

- **procedure** – Procedure object
- **data_filename** – The data filename where the data is or should be stored

**format**(*data*)
Returns a formatted string containing the data to be written to a file

**header**()
Returns a text header to accompany a datafile so that the procedure can be reconstructed

**labels**()
Returns the columns labels as a string to be written to the file

static **load**(*data_filename*, *procedure_class=None*)
Returns a Results object with the associated Procedure object and data

**parse**(*line*)
Returns a dictionary containing the data from the line

static **parse_header**(*header*, *procedure_class=None*)
Returns a Procedure object with the parameters as defined in the header text.

**reload**()
Preforms a full reloading of the file data, neglecting any changes in the comments

pymeasure.experiment.results.**replace_placeholders**(*string*, *procedure*, *date_format='%Y-%m-%d'*, *time_format='%H:%M:%S'*)
Replace placeholders in string with values from procedure parameters.

Replaces the placeholders in the provided string with the values of the associated parameters, as provided by the procedure. This uses the standard python string.format syntax. Apart from the parameter in the procedure (which should be called by their full names) "date" and "time" are also added as optional placeholders.

**Parameters**

- `string` – The string in which the placeholders are to be replaced. Python string.format syntax is used, e.g. "{Parameter Name}" to insert a FloatParameter called "Parameter Name", or "{Parameter Name:.2f}" to also specifically format the parameter.
- `procedure` – The procedure from which to get the parameter values.
- `date_format` – A string to represent how the additional placeholder "date" will be formatted.
- `time_format` – A string to represent how the additional placeholder "time" will be formatted.

`pymeasure.experiment.results.`**`unique_filename`**`(`*directory*, *prefix='DATA'*, *suffix=''*, *ext='csv'*, *dated_folder=False*, *index=True*, *datetimeformat='%Y-%m-%d'*, *procedure=None*`)`

Returns a unique filename based on the directory and prefix

CHAPTER

SIX

# PYMEASURE.DISPLAY

This section contains specific documentation on the classes and methods of the package.

## 6.1 Browser classes

**class** pymeasure.display.browser.**Browser**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtGui.QTreeWidget`

Graphical list view of `Experiment` objects allowing the user to view the status of queued Experiments as well as loading and displaying data from previous runs.

In order that different Experiments be displayed within the same Browser, they must have entries in *DATA_COLUMNS* corresponding to the *measured_quantities* of the Browser.

**add**(*experiment*)

Add a `Experiment` object to the Browser. This function checks to make sure that the Experiment measures the appropriate quantities to warrant its inclusion, and then adds a BrowserItem to the Browser, filling all relevant columns with Parameter data.

**class** pymeasure.display.browser.**BrowserItem**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtGui.QTreeWidgetItem`

Represent a row in the `Browser` tree widget

## 6.2 Curves classes

**class** pymeasure.display.curves.**BufferCurve**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.PlotDataItem`

Creates a curve based on a predefined buffer size and allows data to be added dynamically.

**append**(*x*, *y*)

Appends data to the curve with optional errors

**prepare**(*size*, *dtype=<class 'numpy.float32'>*)

Prepares the buffer based on its size, data type

**class** pymeasure.display.curves.**Crosshairs**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtCore.QObject`

Attaches crosshairs to the a plot and provides a signal with the x and y graph coordinates

**mouseMoved**(*event=None*)

Updates the mouse position upon mouse movement

**update**()

Updates the mouse position based on the data in the plot. For dynamic plots, this is called each time the data changes to ensure the x and y values correspond to those on the display.

class pymeasure.display.curves.**ResultsCurve**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.PlotDataItem`

Creates a curve loaded dynamically from a file through the Results object. The data can be forced to fully reload on each update, useful for cases when the data is changing across the full file instead of just appending.

**update_data**()

Updates the data by polling the results

class pymeasure.display.curves.**ResultsImage**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.ImageItem`

Creates an image loaded dynamically from a file through the Results object.

**colormap**(*x*)

Return mapped color as 0.0-1.0 floats RGBA

**find_img_index**(*x*, *y*)

Finds the integer image indices corresponding to the closest x and y points of the data given some x and y data.

**round_up**(*x*)

Convenience function since numpy rounds to even

## 6.3 Inputs classes

class pymeasure.display.inputs.**BooleanInput**(**args: Any*, ***kwargs: Any*)

Bases: *pymeasure.display.inputs.Input*, `pyqtgraph.Qt.QtGui.QCheckBox`

Checkbox for boolean values, connected to a `BooleanParameter`.

**set_parameter**(*parameter*)

Connects a new parameter to the input box, and initializes the box value.

**Parameters parameter** – parameter to connect.

class pymeasure.display.inputs.**FloatInput**(**args: Any*, ***kwargs: Any*)

Bases: *pymeasure.display.inputs.Input*, `pyqtgraph.Qt.QtGui.QDoubleSpinBox`

Spin input box for floating-point values, connected to a `FloatParameter`.

**See also:**

**Class *ScientificInput*** For inputs in scientific notation.

**set_parameter**(*parameter*)

Connects a new parameter to the input box, and initializes the box value.

**Parameters parameter** – parameter to connect.

class pymeasure.display.inputs.**Input**(*parameter*, ***kwargs*)

Bases: `object`

Mix-in class that connects a *Parameter* object to a GUI input box.

**Parameters parameter** – The parameter to connect to this input box.

**Attr parameter** Read-only property to access the associated parameter.

**property parameter**
The connected parameter object. Read-only property; see `set_parameter()`.

Note that reading this property will have the side-effect of updating its value from the GUI input box.

**set_parameter**(*parameter*)
Connects a new parameter to the input box, and initializes the box value.

**Parameters** **parameter** – parameter to connect.

**update_parameter**()
Update the parameter value with the Input GUI element's current value.

**class** pymeasure.display.inputs.**IntegerInput**(**args: Any*, ***kwargs: Any*)
Bases: `pymeasure.display.inputs.Input`, `pyqtgraph.Qt.QtGui.QSpinBox`

Spin input box for integer values, connected to a `IntegerParameter`.

**set_parameter**(*parameter*)
Connects a new parameter to the input box, and initializes the box value.

**Parameters** **parameter** – parameter to connect.

**class** pymeasure.display.inputs.**ListInput**(**args: Any*, ***kwargs: Any*)
Bases: `pymeasure.display.inputs.Input`, `pyqtgraph.Qt.QtGui.QComboBox`

Dropdown for list values, connected to a `ListParameter`.

**set_parameter**(*parameter*)
Connects a new parameter to the input box, and initializes the box value.

**Parameters** **parameter** – parameter to connect.

**class** pymeasure.display.inputs.**ScientificInput**(**args: Any*, ***kwargs: Any*)
Bases: `pymeasure.display.inputs.Input`, `pyqtgraph.Qt.QtGui.QDoubleSpinBox`

Spinner input box for floating-point values, connected to a `FloatParameter`. This box will display and accept values in scientific notation when appropriate.

**See also:**

**Class `FloatInput`** For a non-scientific floating-point input box.

**set_parameter**(*parameter*)
Connects a new parameter to the input box, and initializes the box value.

**Parameters** **parameter** – parameter to connect.

**class** pymeasure.display.inputs.**StringInput**(**args: Any*, ***kwargs: Any*)
Bases: `pymeasure.display.inputs.Input`, `pyqtgraph.Qt.QtGui.QLineEdit`

String input box connected to a `Parameter`. Parameter subclasses that are string-based may also use this input, but non-string parameters should use more specialised input classes.

## 6.4 Listeners classes

**class** pymeasure.display.listeners.**Monitor**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtCore.QThread`

Monitor listens for status and progress messages from a Worker through a queue to ensure no messages are losts

**class** pymeasure.display.listeners.**QListener**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.thread.StoppableQThread*

Base class for QThreads that need to listen for messages on a ZMQ TCP port and can be stopped by a thread- and process-safe method call

## 6.5 Log classes

**class** pymeasure.display.log.**LogHandler**
Bases: `logging.Handler`

**class Emitter**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtCore.QObject`

**emit**(*record*)
Do whatever it takes to actually log the specified logging record.

This version is intended to be implemented by subclasses and so raises a NotImplementedError.

## 6.6 Manager classes

**class** pymeasure.display.manager.**Experiment**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtCore.QObject`

The Experiment class helps group the *Procedure*, *Results*, and their display functionality. Its function is only a convenient container.

**Parameters**

- **results** – *Results* object
- **curve_list** – *ResultsCurve* list. List of curves associated with an experiment. They could represent different views of the same experiment.
- **browser_item** – *BrowserItem* object

**class** pymeasure.display.manager.**ExperimentQueue**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtCore.QObject`

Represents a Queue of Experiments and allows queries to be easily preformed

**has_next**()
Returns True if another item is on the queue

**next**()
Returns the next experiment on the queue

**class** pymeasure.display.manager.**Manager**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtCore.QObject`

Controls the execution of `Experiment` classes by implementing a queue system in which Experiments are added, removed, executed, or aborted. When instantiated, the Manager is linked to a `Browser` and a PyQtGraph *PlotItem* within the user interface, which are updated in accordance with the execution status of the Experiments.

**abort**()
Aborts the currently running Experiment, but raises an exception if there is no running experiment

**clear**()
Remove all Experiments

**is_running**()
Returns True if a procedure is currently running

**load**(*experiment*)
Load a previously executed Experiment

**next**()
Initiates the start of the next experiment in the queue as long as no other experiments are currently running and there is a procedure in the queue.

**queue**(*experiment*)
Adds an experiment to the queue.

**remove**(*experiment*)
Removes an Experiment

**resume**()
Resume processing of the queue.

## 6.7 Plotter class

**class** pymeasure.display.plotter.**Plotter**(*results*, *refresh_time=0.1*, *linewidth=1*)
Bases: `pymeasure.thread.StoppableThread`

Plotter dynamically plots data from a file through the Results object.

**See also:**

**Tutorial** ***Using the Plotter*** A tutorial and example on using the Plotter and PlotterWindow.

**run**()
Method representing the thread's activity.

You may override this method in a subclass. The standard run() method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the args and kwargs arguments, respectively.

**setup_plot**(*plot*)
This method does nothing by default, but can be overridden by the child class in order to set up custom options for the plot window, via its PlotItem.

**Parameters** **plot** – This window's PlotItem instance.

## 6.8 Qt classes

All Qt imports should reference `pymeasure.display.Qt`, for consistant importing from either PySide or PyQt4.

`Qt.`**`fromUi`**`(`*`**kwargs`*`)`

Returns a Qt object constructed using loadUiType based on its arguments. All QWidget objects in the form class are set in the returned object for easy accessability.

## 6.9 Thread classes

**class** `pymeasure.display.thread.`**`StoppableQThread`**`(`*`*args: Any`*`, `*`**kwargs: Any`*`)`

Bases: `pyqtgraph.Qt.QtCore.QThread`

Base class for QThreads which require the ability to be stopped by a thread-safe method call

**`join`**`(`*`timeout=0`*`)`

Joins the current thread and forces it to stop after the timeout if necessary

**Parameters** **`timeout`** – Timeout duration in seconds

## 6.10 Widget classes

**class** `pymeasure.display.widgets.browser_widget.`**`BrowserWidget`**`(`*`*args: Any`*`, `*`**kwargs: Any`*`)`

Bases: `pyqtgraph.Qt.QtGui.QWidget`

Widget wrapper for *`Browser`* class

**class** `pymeasure.display.widgets.directory_widget.`**`DirectoryLineEdit`**`(`*`*args: Any`*`, `*`**kwargs: Any`*`)`

Bases: `pyqtgraph.Qt.QtGui.QLineEdit`

Widget that allows to choose a directory path. A completer is implemented for quick completion. A browse button is available.

**class** `pymeasure.display.widgets.estimator_widget.`**`EstimatorThread`**`(`*`*args: Any`*`, `*`**kwargs: Any`*`)`

Bases: *`pymeasure.display.thread.StoppableQThread`*

**class** `pymeasure.display.widgets.estimator_widget.`**`EstimatorWidget`**`(`*`*args: Any`*`, `*`**kwargs: Any`*`)`

Bases: `pyqtgraph.Qt.QtGui.QWidget`

Widget that allows to display up-front estimates of the measurement procedure.

This widget relies on a *get_estimates* method of the *`Procedure`* class. *get_estimates* is expected to return a list of tuples, where each tuple contains two strings: a label and the estimate.

If the *`SequencerWidget`* is also used, it is possible to ask for the current sequencer or its length by asking for two keyword arguments in the Implementation of the *get_estimates* function: *sequence* and *sequence_length*, respectively.

**`check_get_estimates_signature`**`()`

Method that checks the signature of the get_estimates function. It checks which input arguments are allowed and, if the output is correct for the EstimatorWidget, stores the number of estimates.

**`display_estimates`**`(`*`estimates`*`)`

Method that updates the shown estimates for the given set of estimates.

**Parameters** **`estimates`** – The set of estimates to be shown in the form of a list of tuples of (2) strings

**get_estimates**()

Method that makes a procedure with the currently entered parameters and returns the estimates for these parameters.

**update_estimates**()

Method that gets and displays the estimates. Implemented for connecting to the 'update'-button.

class pymeasure.display.widgets.image_frame.**ImageFrame**(**args: Any*, ***kwargs: Any*)

Bases: `pymeasure.display.widgets.plot_frame.PlotFrame`

Extends `PlotFrame` to plot also axis Z using colors

**ResultsClass**

alias of `pymeasure.display.curves.ResultsImage`

class pymeasure.display.widgets.image_widget.**ImageWidget**(**args: Any*, ***kwargs: Any*)

Bases: `pymeasure.display.widgets.tab_widget.TabWidget`, `pyqtgraph.Qt.QtGui.QWidget`

Extends the `ImageFrame` to allow different columns of the data to be dynamically chosen

**load**(*curve*)

Add curve to widget

**new_curve**(*results*, *color=pyqtgraph.intColor*, ***kwargs*)

Creates a new image

**remove**(*curve*)

Remove curve from widget

class pymeasure.display.widgets.inputs_widget.**InputsWidget**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtGui.QWidget`

Widget wrapper for various *Inputs classes*

**get_procedure**()

Returns the current procedure

class pymeasure.display.widgets.log_widget.**LogWidget**(**args: Any*, ***kwargs: Any*)

Bases: `pymeasure.display.widgets.tab_widget.TabWidget`, `pyqtgraph.Qt.QtGui.QWidget`

Widget to display logging information in GUI

It is recommended to include this widget in all subclasses of `ManagedWindowBase`

class pymeasure.display.widgets.plot_frame.**PlotFrame**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtGui.QFrame`

Combines a PyQtGraph Plot with Crosshairs. Refreshes the plot based on the refresh_time, and allows the axes to be changed on the fly, which updates the plotted data

**ResultsClass**

alias of `pymeasure.display.curves.ResultsCurve`

**parse_axis**(*axis*)

Returns the units of an axis by searching the string

class pymeasure.display.widgets.plot_widget.**PlotWidget**(**args: Any*, ***kwargs: Any*)

Bases: `pymeasure.display.widgets.tab_widget.TabWidget`, `pyqtgraph.Qt.QtGui.QWidget`

Extends `PlotFrame` to allow different columns of the data to be dynamically chosen

**load**(*curve*)

Add curve to widget

**new_curve**(*results*, *color=pyqtgraph.intColor*, ***kwargs*)
Create a new curve

**remove**(*curve*)
Remove curve from widget

**set_color**(*curve*, *color*)
Change the color of the pen of the curve

class pymeasure.display.widgets.results_dialog.**ResultsDialog**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtGui.QFileDialog`

Widget that displays a dialog box for loading a past experiment run. It shows a preview of curves from the results file when selected in the dialog box.

This widget used by the *open_experiment* method in `ManagedWindowBase` class

exception pymeasure.display.widgets.sequencer_widget.**SequenceEvaluationException**
Bases: `Exception`

Raised when the evaluation of a sequence string goes wrong.

class pymeasure.display.widgets.sequencer_widget.**SequencerWidget**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtGui.QWidget`

Widget that allows to generate a sequence of measurements with varying parameters. Moreover, one can write a simple text file to easily load a sequence.

Currently requires a queue function of the ManagedWindow to have a "procedure" argument.

static **eval_string**(*string*, *name=None*, *depth=None*)
Evaluate the given string. The string is evaluated using a list of pre-defined functions that are deemed safe to use, to prevent the execution of malicious code. For this purpose, also any built-in functions or global variables are not available.

**Parameters**

- **string** – String to be interpreted.
- **name** – Name of the to-be-interpreted string, only used for error messages.
- **depth** – Depth of the to-be-interpreted string, only used for error messages.

**get_sequence_from_tree**()
Generate a list of parameters from the sequence tree.

**load_sequence**(***, *fileName=None*)
Load a sequence from a .txt file.

**Parameters** **fileName** – Filename (string) of the to-be-loaded file.

**queue_sequence**()
Obtain a list of parameters from the sequence tree, enter these into procedures, and queue these procedures.

class pymeasure.display.widgets.tab_widget.**TabWidget**(*name*, **args*, ***kwargs*)
Bases: `object`

Utility class to define default implementation for some basic methods.

When defining a widget to be used in subclasses of `ManagedWindowBase`, users should inherit from this class and provide an implementation of these methods

**load**(*curve*)
Add curve to widget

**new_curve**(**args*, ***kwargs*)
Create a new curve

**remove**(*curve*)
Remove curve from widget

**set_color**(*curve*, *color*)
Set color for widget

## 6.11 Windows classes

**class** pymeasure.display.windows.**ManagedImageWindow**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.windows.ManagedWindow*

Display experiment output with an `ImageWidget` class.

**Parameters**

- **procedure_class** – procedure class describing the experiment (see *Procedure*)
- **x_axis** – the data-column for the x-axis of the plot, cannot be changed afterwards for the image-plot
- **y_axis** – the data-column for the y-axis of the plot, cannot be changed afterwards for the image-plot
- **z_axis** – the initial data-column for the z-axis of the plot, can be changed afterwards
- ****kwargs** – optional keyword arguments that will be passed to *ManagedWindow*

**class** pymeasure.display.windows.**ManagedWindow**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.windows.ManagedWindowBase*

Display experiment output with an `PlotWidget` class.

**See also:**

**Tutorial** ***Using the ManagedWindow*** A tutorial and example on the basic configuration and usage of ManagedWindow.

**Parameters**

- **procedure_class** – procedure class describing the experiment (see *Procedure*)
- **x_axis** – the initial data-column for the x-axis of the plot
- **y_axis** – the initial data-column for the y-axis of the plot
- **linewidth** – linewidth for the displayed curves, default is 1
- ****kwargs** – optional keyword arguments that will be passed to *ManagedWindowBase*

**class** pymeasure.display.windows.**ManagedWindowBase**(**args: Any*, ***kwargs: Any*)
Bases: `pyqtgraph.Qt.QtGui.QMainWindow`

Base class for GUI experiment management .

The ManagedWindowBase provides an interface for inputting experiment parameters, running several experiments (*Procedure*), plotting result curves, and listing the experiments conducted during a session.

The ManagedWindowBase uses a Manager to control Workers in a Queue, and provides a simple interface. The *queue()* method must be overridden by the child class.

The ManagedWindowBase allow user to define a set of widget that display information about the experiment. The information displayed may include: plots, tabular view, logging information,. . .

This class is not intended to be used directy, but it should be subclassed to provide some appropriate widget list. Example of classes usable as element of widget list are:

- `LogWidget`
- `PlotWidget`
- `ImageWidget`

Of course, users can define its own widget making sure that inherits from `TabWidget`.

Examples of ready to use classes inherited from ManagedWindowBase are:

- *`ManagedWindow`*
- *`ManagedImageWindow`*

**See also:**

**Tutorial** ***Using the ManagedWindow*** A tutorial and example on the basic configuration and usage of ManagedWindow.

Parameters for `__init__` constructor.

**Parameters**

- **`procedure_class`** – procedure class describing the experiment (see *`Procedure`*)
- **`widget_list`** – list of widget to be displayed in the GUI
- **`inputs`** – list of *`Parameter`* instance variable names, which the display will generate graphical fields for
- **`displays`** – list of *`Parameter`* instance variable names displayed in the browser window
- **`log_channel`** – `logging.Logger` instance to use for logging output
- **`log_level`** – logging level
- **`parent`** – Parent widget or `None`
- **`sequencer`** – a boolean stating whether or not the sequencer has to be included into the window
- **`sequencer_inputs`** – either `None` or a list of the parameter names to be scanned over. If no list of parameters is given, the parameters displayed in the manager queue are used.
- **`sequence_file`** – simple text file to quickly load a pre-defined sequence with the code:*Load sequence* button
- **`inputs_in_scrollarea`** – boolean that display or hide a scrollbar to the input area
- **`directory_input`** – specify, if present, where the experiment's result will be saved.
- **`hide_groups`** – a boolean controlling whether parameter groups are hidden (True, default) or disabled/grayed-out (False) when the group conditions are not met.

`open_file_externally`(*filename*)

Method to open the datafile using an external editor or viewer. Uses the default application to open a datafile of this filetype, but can be overridden by the child class in order to open the file in another application of choice.

**queue**(*procedure=None*)

Abstract method, which must be overridden by the child class.

Implementations must call `self.manager.queue(experiment)` and pass an `experiment` (*Experiment*) object which contains the *Results* and *Procedure* to be run.

The optional *procedure* argument is not required for a basic implementation, but is required when the `SequencerWidget` is used.

For example:

```
def queue(self):
    filename = unique_filename('results', prefix="data") # from pymeasure.
↪experiment

    procedure = self.make_procedure() # Procedure class was passed at␣
↪construction
    results = Results(procedure, filename)
    experiment = self.new_experiment(results)

    self.manager.queue(experiment)
```

**set_parameters**(*parameters*)

This method should be overwritten by the child class. The parameters argument is a dictionary of Parameter objects. The Parameters should overwrite the GUI values so that a user can click "Queue" to capture the same parameters.

**class** pymeasure.display.windows.**PlotterWindow**(**args: Any*, ***kwargs: Any*)

Bases: `pyqtgraph.Qt.QtGui.QMainWindow`

A window for plotting experiment results. Should not be instantiated directly, but only via the *Plotter* class.

**See also:**

**Tutorial** ***Using the Plotter*** A tutorial and example code for using the Plotter and PlotterWindow.

**check_stop**()

Checks if the Plotter should stop and exits the Qt main loop if so

CHAPTER

SEVEN

# PYMEASURE.INSTRUMENTS

This section contains documentation on the instrument classes.

## 7.1 Instrument classes

**class** pymeasure.instruments.**Instrument**(*adapter*, *name*, *includeSCPI=True*, ***kwargs*)

The base class for all Instrument definitions.

It makes use of one of the *Adapter* classes for communication with the connected hardware device. This decouples the instrument/command definition from the specific communication interface used.

When `adapter` is a string, this is taken as an appropriate resource name. Depending on your installed VISA library, this can be something simple like `COM1` or `ASRL2`, or a more complicated VISA resource name defining the target of your connection.

When `adapter` is an integer, a GPIB resource name is created based on that. In either case a *VISAAdapter* is constructed based on that resource name. Keyword arguments can be used to further configure the connection.

Otherwise, the passed *Adapter* object is used and any keyword arguments are discarded.

This class defines basic SCPI commands by default. This can be disabled with `includeSCPI` for instruments not compatible with the standard SCPI commands.

**Parameters**

- **adapter** – A string, integer, or *Adapter* subclass object
- **name** (*string*) – The name of the instrument. Often the model designation by default.
- **includeSCPI** – A boolean, which toggles the inclusion of standard SCPI commands
- ****kwargs** – In case `adapter` is a string or integer, additional arguments passed on to *VISAAdapter* (check there for details). Discarded otherwise.

**ask**(*command*)

Writes the command to the instrument through the adapter and returns the read response.

**Parameters** **command** – command string to be sent to the instrument

**check_errors**()

Read all errors from the instrument.

**Returns** list of error entries

**clear**()

Clears the instrument status byte

**property complete**

This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**static control**(*get_command*, *set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *get_process=<function Instrument.<lambda>>*, *set_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_set_errors=False*, *check_get_errors=False*, *dynamic=False*, ***kwargs*)

Returns a property for the class based on the supplied commands. This property may be set and read from the instrument. See also `measurement()` and `setting()`.

**Parameters**

- **get_command** – A string command that asks for the value, set to *None* if get is not supported (see also `setting()`).
- **set_command** – A string command that writes the value, set to *None* if set is not supported (see also `measurement()`).
- **docs** – A docstring that will be included in the documentation
- **validator** – A function that takes both a value and a group of valid values and returns a valid value, while it otherwise raises an exception
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map
- **get_process** – A function that take a value and allows processing before value mapping, returning the processed value
- **set_process** – A function that takes a value and allows processing before value mapping, returning the processed value
- **command_process** – A function that takes a command and allows processing before executing the command
- **check_set_errors** – Toggles checking errors after setting
- **check_get_errors** – Toggles checking errors after getting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses.

Example of usage of dynamic parameter is as follows:

```python
class GenericInstrument(Instrument):
    center_frequency = Instrument.control(
        ":SENS:FREQ:CENT?;", ":SENS:FREQ:CENT %e GHz;",
        " A floating point property that represents the frequency ... ",
        validator=strict_range,
        # Redefine this in subclasses to reflect actual instrument value:
        values=(1, 20),
        dynamic=True  # enable changing property parameters on-the-fly
    )

class SpecificInstrument(GenericInstrument):
    # Identical to GenericInstrument, except for frequency range
```

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```
    # Override the "values" parameter of the "center_frequency" property
    center_frequency_values = (1, 10) # Redefined at subclass level

instrument = SpecificInstrument()
instrument.center_frequency_values = (1, 6e9) # Redefined at instance level
```

**Warning:** Unexpected side effects when using dynamic properties

Users must pay attention when using dynamic properties, since definition of class and/or instance attributes matching specific patterns could have unwanted side effect. The attribute name pattern *property_param*, where *property* is the name of the dynamic property (e.g. *center_frequency* in the example) and *param* is any of this method parameters name except *dynamic* and *docs* (e.g. *values* in the example) has to be considered reserved for dynamic property control.

**property id**
Requests and returns the identification of the instrument.

**static measurement**(*get_command*, *docs*, *values=()*, *map_values=None*, *get_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_get_errors=False*, *dynamic=False*, ***kwargs*)
Returns a property for the class based on the supplied commands. This is a measurement quantity that may only be read from the instrument, not set.

**Parameters**

- **get_command** – A string command that asks for the value
- **docs** – A docstring that will be included in the documentation
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map
- **get_process** – A function that take a value and allows processing before value mapping, returning the processed value
- **command_process** – A function that take a command and allows processing before executing the command, for getting
- **check_get_errors** – Toggles checking errors after getting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses. See `control()` for an usage example.

**property options**
Requests and returns the device options installed.

**read**()
Reads from the instrument through the adapter and returns the response.

**reset**()
Resets the instrument.

**static setting**(*set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *set_process=<function Instrument.<lambda>>*, *check_set_errors=False*, *dynamic=False*, ***kwargs*)
Returns a property for the class based on the supplied commands. This property may be set, but raises an

exception when being read from the instrument.

**Parameters**

- **set_command** – A string command that writes the value
- **docs** – A docstring that will be included in the documentation
- **validator** – A function that takes both a value and a group of valid values and returns a valid value, while it otherwise raises an exception
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map
- **set_process** – A function that takes a value and allows processing before value mapping, returning the processed value
- **check_set_errors** – Toggles checking errors after setting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses. See `control()` for an usage example.

**shutdown**()

Brings the instrument to a safe and stable state

**property status**

Requests and returns the status byte and Master Summary Status bit.

**values**(*command*, ***kwargs*)

Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

**write**(*command*)

Writes the command to the instrument through the adapter.

**Parameters command** – command string to be sent to the instrument

**class** pymeasure.instruments.fakes.**FakeInstrument**(*adapter=None*, *name=None*, *includeSCPI=False*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Provides a fake implementation of the Instrument class for testing purposes.

**static control**(*get_command*, *set_command*, *docs*, *validator=<function FakeInstrument.<lambda>>*, *values=()*, *map_values=False*, *get_process=<function FakeInstrument.<lambda>>*, *set_process=<function FakeInstrument.<lambda>>*, *check_set_errors=False*, *check_get_errors=False*, ***kwargs*)

Fake Instrument.control.

Strip commands and only store and return values indicated by format strings to mimic many simple commands. This is analogous how the tests in test_instrument are handled.

**class** pymeasure.instruments.fakes.**SwissArmyFake**(*wait=0.1*, ***kwargs*)

Bases: `pymeasure.instruments.fakes.FakeInstrument`

Dummy instrument class useful for testing.

Like a Swiss Army knife, this class provides multi-tool functionality in the form of streams of multiple types of fake data. Data streams that can currently be generated by this class include 'voltages', sinusoidal 'waveforms', and mono channel 'image data'.

**property frame**

Get a new image frame.

**property frame_format**
Format for image data returned from the get_frame() method. Allowed values are: mono_8: single channel 8-bit image. mono_16: single channel 16-bit image.

**property frame_height**
Image frame height in pixels.

**property frame_width**
Image frame width in pixels.

**property time**
Float property for elapsed time.

**property voltage**
Get the voltage.

**property wave**
Return a waveform.

## 7.2 Validator functions

Validators are used in conjunction with the *Instrument.control* function to allow properties with complex restrictions for valid values. They are described in more detail in the *Advanced properties* section.

pymeasure.instruments.validators.**discreteTruncate**(*number*, *discreteSet*)
Truncates the number to the closest element in the positive discrete set. Returns False if the number is larger than the maximum value or negative.

pymeasure.instruments.validators.**joined_validators**(**validators*)
Returns a validator function that represents a list of validators joined together.

A value passed to the validator is returned if it passes any validator (not all of them). Otherwise it raises a ValueError.

Note: the joined validator expects `values` to be a sequence of `values` appropriate for the respective validators (often sequences themselves).

**Example**

```
>>> from pymeasure.instruments.validators import strict_discrete_set, strict_range
>>> from pymeasure.instruments.validators import joined_validators
>>> joined_v = joined_validators(strict_discrete_set, strict_range)
>>> values = [['MAX','MIN'], range(10)]
>>> joined_v(5, values)
5
>>> joined_v('MAX', values)
'MAX'
>>> joined_v('NONSENSE', values)
Traceback (most recent call last):
...
ValueError: Value of NONSENSE does not match any of the joined validators
```

**Parameters** **validators** – an iterable of other validators

pymeasure.instruments.validators.**modular_range**(*value*, *values*)
Provides a validator function that returns the value if it is in the range. Otherwise it returns the value, modulo the max of the range.

**Parameters**

- `value` – a value to test
- `values` – A set of values that are valid

`pymeasure.instruments.validators.modular_range_bidirectional(value, values)`

Provides a validator function that returns the value if it is in the range. Otherwise it returns the value, modulo the max of the range. Allows negative values.

**Parameters**

- `value` – a value to test
- `values` – A set of values that are valid

`pymeasure.instruments.validators.strict_discrete_range(value, values, step)`

Provides a validator function that returns the value if its value is less than the maximum and greater than the minimum of the range and is a multiple of step. Otherwise it raises a ValueError.

**Parameters**

- `value` – A value to test
- `values` – A range of values (range, list, etc.)
- `step` – Minimum stepsize (resolution limit)

**Raises** ValueError if the value is out of the range

`pymeasure.instruments.validators.strict_discrete_set(value, values)`

Provides a validator function that returns the value if it is in the discrete set. Otherwise it raises a ValueError.

**Parameters**

- `value` – A value to test
- `values` – A set of values that are valid

**Raises** ValueError if the value is not in the set

`pymeasure.instruments.validators.strict_range(value, values)`

Provides a validator function that returns the value if its value is less than or equal to the maximum and greater than or equal to the minimum of `values`. Otherwise it raises a ValueError.

**Parameters**

- `value` – A value to test
- `values` – A range of values (range, list, etc.)

**Raises** ValueError if the value is out of the range

`pymeasure.instruments.validators.truncated_discrete_set(value, values)`

Provides a validator function that returns the value if it is in the discrete set. Otherwise, it returns the smallest value that is larger than the value.

**Parameters**

- `value` – A value to test
- `values` – A set of values that are valid

`pymeasure.instruments.validators.truncated_range(value, values)`

Provides a validator function that returns the value if it is in the range. Otherwise it returns the closest range bound.

**Parameters**

- **value** – A value to test
- **values** – A set of values that are valid

## 7.3 Comedi data acquisition

The Comedi libraries provide a convenient method for interacting with data acquisition cards, but are restricted to Linux compatible operating systems.

`pymeasure.instruments.comedi.getAI(device, channel, range=None)`
Returns the analog input channel as specified for a given device

`pymeasure.instruments.comedi.getAO(device, channel, range=None)`
Returns the analog output channel as specified for a given device

`pymeasure.instruments.comedi.readAI(device, channel, range=None, count=1)`
Reads a single measurement (count==1) from the analog input channel of the device specified. Multiple readings can be preformed with count not equal to one, which are seperated by an arbitrary time

`pymeasure.instruments.comedi.writeAO(device, channel, voltage, range=None)`
Writes a single voltage to the analog output channel of the device specified

## 7.4 Resource Manager

The list_resources function provides an interface to check connected instruments interactively.

`pymeasure.instruments.list_resources()`
Prints the available resources, and returns a list of VISA resource names

```
resources = list_resources()
#prints (e.g.)
    #0 : GPIB0::22::INSTR : Agilent Technologies,34410A,******
    #1 : GPIB0::26::INSTR : Keithley Instruments Inc., Model 2612, *****
dmm = Agilent34410(resources[0])
```

Instruments by manufacturer:

## 7.5 Advantest

This section contains specific documentation on the Advantest instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.5.1 Advantest R3767CG Vector Network Analyzer

**class** pymeasure.instruments.advantest.advantestR3767CG.**AdvantestR3767CG**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Advantest R3767CG VNA. Implements controls to change the analysis range and to retreve the data for the trace.

**property center_frequency**
Center Frequency in Hz

**property id**
Reads the instrument identification

**property span_frequency**
Span Frequency in Hz

**property start_frequency**
Starting frequency in Hz

**property stop_frequency**
Stoping frequency in Hz

**property trace_1**
Reads the Data array from trace 1 after formatting

## 7.6 Agilent

This section contains specific documentation on the Agilent instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.6.1 Agilent 8257D Signal Generator

**class** pymeasure.instruments.agilent.**Agilent8257D**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 8257D Signal Generator and provides a high-level interface for interacting with the instrument.

```
generator = Agilent8257D("GPIB::1")

generator.power = 0                    # Sets the output power to 0 dBm
generator.frequency = 5                # Sets the output frequency to 5 GHz
generator.enable()                     # Enables the output
```

**property amplitude_depth**
A floating point property that controls the amplitude modulation in precent, which can take values from 0 to 100 %.

**property amplitude_source**
A string property that controls the source of the amplitude modulation signal, which can take the values: 'internal', 'internal 2', 'external', and 'external 2'.

**property center_frequency**
A floating point property that represents the center frequency in Hz. This property can be set.

**config_amplitude_modulation**(*frequency=1000.0*, *depth=100.0*, *shape='sine'*)
Configures the amplitude modulation of the output signal.

**Parameters**

- **frequency** – A modulation frequency for the internal oscillator
- **depth** – A linear depth precentage
- **shape** – A string that describes the shape for the internal oscillator

**config_low_freq_out**(*source='internal'*, *amplitude=3*)
Configures the low-frequency output signal.

**Parameters**

- **source** – The source for the low-frequency output signal.
- **amplitude** – Amplitude of the low-frequency output

**config_pulse_modulation**(*frequency=1000.0*, *input='square'*)
Configures the pulse modulation of the output signal.

**Parameters**

- **frequency** – A pulse rate frequency in Hertz
- **input** – A string that describes the internal pulse input

**config_step_sweep**()
Configures a step sweep through frequency

**disable**()
Disables the output of the signal.

**disable_amplitude_modulation**()
Disables amplitude modulation of the output signal.

**disable_low_freq_out**()
Disables low frequency output

**disable_modulation**()
Disables the signal modulation.

**disable_pulse_modulation**()
Disables pulse modulation of the output signal.

**property dwell_time**
A floating point property that represents the settling time in seconds at the current frequency or power setting. This property can be set.

**enable**()
Enables the output of the signal.

**enable_amplitude_modulation**()
Enables amplitude modulation of the output signal.

**enable_low_freq_out**()
Enables low frequency output

**enable_pulse_modulation**()
Enables pulse modulation of the output signal.

**property frequency**
A floating point property that represents the output frequency in Hz. This property can be set.

**property has_amplitude_modulation**
Reads a boolean value that is True if the amplitude modulation is enabled.

**property has_modulation**
Reads a boolean value that is True if the modulation is enabled.

**property has_pulse_modulation**
Reads a boolean value that is True if the pulse modulation is enabled.

**property internal_frequency**
A floating point property that controls the frequency of the internal oscillator in Hertz, which can take values from 0.5 Hz to 1 MHz.

**property internal_shape**
A string property that controls the shape of the internal oscillations, which can take the values: 'sine', 'triangle', 'square', 'ramp', 'noise', 'dual-sine', and 'swept-sine'.

**property is_enabled**
Reads a boolean value that is True if the output is on.

**property low_freq_out_amplitude**
A floating point property that controls the peak voltage (amplitude) of the low frequency output in volts, which can take values from 0-3.5V

**property low_freq_out_source**
A string property which controls the source of the low frequency output, which can take the values 'internal [2]' for the inernal source, or 'function [2]' for an internal function generator which can be configured.

**property power**
A floating point property that represents the output power in dBm. This property can be set.

**property pulse_frequency**
A floating point property that controls the pulse rate frequency in Hertz, which can take values from 0.1 Hz to 10 MHz.

**property pulse_input**
A string property that controls the internally generated modulation input for the pulse modulation, which can take the values: 'square', 'free-run', 'triggered', 'doublet', and 'gated'.

**property pulse_source**
A string property that controls the source of the pulse modulation signal, which can take the values: 'internal', 'external', and 'scalar'.

**shutdown()**
Shuts down the instrument by disabling any modulation and the output signal.

**property start_frequency**
A floating point property that represents the start frequency in Hz. This property can be set.

**property start_power**
A floating point property that represents the start power in dBm. This property can be set.

**start_step_sweep()**
Starts a step sweep.

**property step_points**
An integer number of points in a step sweep. This property can be set.

**property stop_frequency**
A floating point property that represents the stop frequency in Hz. This property can be set.

**property stop_power**
A floating point property that represents the stop power in dBm. This property can be set.

**stop_step_sweep**()
Stops a step sweep.

### 7.6.2 Agilent 8722ES Vector Network Analyzer

**class** pymeasure.instruments.agilent.**Agilent8722ES**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Agilent8722ES Vector Network Analyzer and provides a high-level interface for taking scans of the scattering parameters.

**property averages**
An integer representing the number of averages to take. Note that averaging must be enabled for this to take effect. This property can be set.

**property averaging_enabled**
A bool that indicates whether or not averaging is enabled. This property can be set.

**property data**
Returns the real and imaginary data from the last scan

**property data_complex**
Returns the complex power from the last scan

**property data_log_magnitude**
Returns the absolute magnitude values in dB from the last scan

**property data_magnitude**
Returns the absolute magnitude values from the last scan

**property data_phase**
Returns the phase in degrees from the last scan

**disable_averaging**()
Disables averaging

**enable_averaging**()
Enables averaging

**property frequencies**
Returns a list of frequencies from the last scan

**is_averaging**()
Returns True if averaging is enabled

**log_magnitude**(*real*, *imaginary*)
Returns the magnitude in dB from a real and imaginary number or numpy arrays

**magnitude**(*real*, *imaginary*)
Returns the magnitude from a real and imaginary number or numpy arrays

**phase**(*real*, *imaginary*)
Returns the phase in degrees from a real and imaginary number or numpy arrays

**scan**(*averages=None*, *blocking=None*, *timeout=None*, *delay=None*)
Initiates a scan with the number of averages specified and blocks until the operation is complete.

**scan_continuous**()
Initiates a continuous scan

**property scan_points**
Gets the number of scan points

**scan_single**()
Initiates a single scan

**set_IF_bandwidth**(*bandwidth*)
Sets the resolution bandwidth (IF bandwidth)

**set_averaging**(*averages*)
Sets the number of averages and enables/disables averaging. Should be between 1 and 999

**set_fixed_frequency**(*frequency*)
Sets the scan to be of only one frequency in Hz

**property start_frequency**
A floating point property that represents the start frequency in Hz. This property can be set.

**property stop_frequency**
A floating point property that represents the stop frequency in Hz. This property can be set.

**property sweep_time**
A floating point property that represents the sweep time in seconds. This property can be set.

### 7.6.3 Agilent E4408B Spectrum Analyzer

**class** pymeasure.instruments.agilent.**AgilentE4408B**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the AgilentE4408B Spectrum Analyzer and provides a high-level interface for taking scans of high-frequency spectrums

**property center_frequency**
A floating point property that represents the center frequency in Hz. This property can be set.

**property frequencies**
Returns a numpy array of frequencies in Hz that correspond to the current settings of the instrument.

**property frequency_points**
An integer property that represents the number of frequency points in the sweep. This property can take values from 101 to 8192.

**property frequency_step**
A floating point property that represents the frequency step in Hz. This property can be set.

**property start_frequency**
A floating point property that represents the start frequency in Hz. This property can be set.

**property stop_frequency**
A floating point property that represents the stop frequency in Hz. This property can be set.

**property sweep_time**
A floating point property that represents the sweep time in seconds. This property can be set.

**trace**(*number=1*)
Returns a numpy array of the data for a particular trace based on the trace number (1, 2, or 3).

**trace_df**(*number=1*)
Returns a pandas DataFrame containing the frequency and peak data for a particular trace, based on the trace number (1, 2, or 3).

### 7.6.4 Agilent E4980 LCR Meter

`class pymeasure.instruments.agilent.AgilentE4980(adapter, **kwargs)`

Bases: `pymeasure.instruments.instrument.Instrument`

Represents LCR meter E4980A/AL

`property ac_current`

AC current level, in Amps

`property ac_voltage`

AC voltage level, in Volts

`aperture(time=None, averages=1)`

Set and get aperture.

**Parameters**

- **time** – integration time as string: SHORT, MED, LONG (case insensitive); if None, get values
- **averages** – number of averages, numeric

`freq_sweep(freq_list, return_freq=False)`

Run frequency list sweep using sequential trigger.

**Parameters**

- **freq_list** – list of frequencies
- **return_freq** – if True, returns the frequencies read from the instrument

Returns values as configured with `mode`

`property frequency`

AC frequency (range depending on model), in Hertz

`property impedance`

Measured data A and B, according to `mode`

`property mode`

Select quantities to be measured:

- CPD: Parallel capacitance [F] and dissipation factor [number]
- CPQ: Parallel capacitance [F] and quality factor [number]
- CPG: Parallel capacitance [F] and parallel conductance [S]
- CPRP: Parallel capacitance [F] and parallel resistance [Ohm]
- CSD: Series capacitance [F] and dissipation factor [number]
- CSQ: Series capacitance [F] and quality factor [number]
- CSRS: Series capacitance [F] and series resistance [Ohm]

- LPD: Parallel inductance [H] and dissipation factor [number]
- LPQ: Parallel inductance [H] and quality factor [number]
- LPG: Parallel inductance [H] and parallel conductance [S]
- LPRP: Parallel inductance [H] and parallel resistance [Ohm]

- LSD: Series inductance [H] and dissipation factor [number]

- LSQ: Seriesinductance [H] and quality factor [number]
- LSRS: Series inductance [H] and series resistance [Ohm]
- RX: Resitance [Ohm] and reactance [Ohm]
- ZTD: Impedance, magnitude [Ohm] and phase [deg]
- ZTR: Impedance, magnitude [Ohm] and phase [rad]
- GB: Conductance [S] and susceptance [S]
- YTD: Admittance, magnitude [Ohm] and phase [deg]
- YTR: Admittance magnitude [Ohm] and phase [rad]

`property trigger_source`

**Select trigger source; accept the values:**

- HOLD: manual
- INT: internal
- BUS: external bus (GPIB/LAN/USB)
- EXT: external connector

### 7.6.5 Agilent 34410A Multimeter

`class pymeasure.instruments.agilent.Agilent34410A(adapter, **kwargs)`

Bases: `pymeasure.instruments.instrument.Instrument`

Represent the HP/Agilent/Keysight 34410A and related multimeters.

Implemented measurements: voltage_dc, voltage_ac, current_dc, current_ac, resistance, resistance_4w

`property current_ac`
AC current, in Amps

`property current_dc`
DC current, in Amps

`property resistance`
Resistance, in Ohms

`property resistance_4w`
Four-wires (remote sensing) resistance, in Ohms

`property voltage_ac`
AC voltage, in Volts

`property voltage_dc`
DC voltage, in Volts

### 7.6.6 HP/Agilent/Keysight 34450A Digital Multimeter

**class** pymeasure.instruments.agilent.**Agilent34450A**(*adapter*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Represent the HP/Agilent/Keysight 34450A and related multimeters.

```
dmm = Agilent34450A("USB0::...")
dmm.reset()
dmm.configure_voltage()
print(dmm.voltage)
dmm.shutdown()
```

**beep**()

Sounds a system beep.

**property capacitance**

Reads a capacitance measurement in Farads, based on the active `mode`.

**property capacitance_auto_range**

A boolean property that toggles auto ranging for capacitance.

**property capacitance_range**

A property that controls the capacitance range in Farads, which can take values 1E-9, 10E-9, 100E-9, 1E-6, 10E-6, 100E-6, 1E-3, 10E-3, as well as “MIN”, “MAX”, or “DEF” (1E-6). Auto-range is disabled when this property is set.

**configure_capacitance**(*capacitance_range='AUTO'*)

Configures the instrument to measure capacitance.

**Parameters** **capacitance_range** – A capacitance in Farads to set the capacitance range, can be 1E-9, 10E-9, 100E-9, 1E-6, 10E-6, 100E-6, 1E-3, 10E-3, as well as “MIN”, “MAX”, “DEF” (1E-6), or “AUTO”.

**configure_continuity**()

Configures the instrument to measure continuity.

**configure_current**(*current_range='AUTO'*, *ac=False*, *resolution='DEF'*)

Configures the instrument to measure current.

**Parameters**

- **current_range** – A current in Amps to set the current range. DC values can be 100E-6, 1E-3, 10E-3, 100E-3, 1, 10, as well as “MIN”, “MAX”, “DEF” (100 mA), or “AUTO”. AC values can be 10E-3, 100E-3, 1, 10, as well as “MIN”, “MAX”, “DEF” (100 mA), or “AUTO”.
- **ac** – False for DC current, and True for AC current
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as “MIN”, “MAX”, or “DEF” (1.50E-6).

**configure_diode**()

Configures the instrument to measure diode voltage.

**configure_frequency**(*measured_from='voltage_ac'*, *measured_from_range='AUTO'*, *aperture='DEF'*)

Configures the instrument to measure frequency.

**Parameters**

- **measured_from** – “voltage_ac” or “current_ac”

- **measured_from_range** – range of measured_from. AC voltage can have ranges 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO". AC current can have ranges 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", "DEF" (100 mA), or "AUTO".
- **aperture** – Aperture time in Seconds, can be 100 ms, 1 s, as well as "MIN", "MAX", or "DEF" (1 s).

**configure_resistance**(*resistance_range='AUTO'*, *wires=2*, *resolution='DEF'*)
Configures the instrument to measure resistance.

**Parameters**

- **resistance_range** – A resistance in Ohms to set the resistance range, can be 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", "DEF" (1E3), or "AUTO".
- **wires** – Number of wires used for measurement, can be 2 or 4.
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**configure_temperature**()
Configures the instrument to measure temperature.

**configure_voltage**(*voltage_range='AUTO'*, *ac=False*, *resolution='DEF'*)
Configures the instrument to measure voltage.

**Parameters**

- **voltage_range** – A voltage in Volts to set the voltage range. DC values can be 100E-3, 1, 10, 100, 1000, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO". AC values can be 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO".
- **ac** – False for DC voltage, True for AC voltage
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**property continuity**
Reads a continuity measurement in Ohms, based on the active `mode`.

**property current**
Reads a DC current measurement in Amps, based on the active `mode`.

**property current_ac**
Reads an AC current measurement in Amps, based on the active `mode`.

**property current_ac_auto_range**
A boolean property that toggles auto ranging for AC current.

**property current_ac_range**
A property that controls the AC current range in Amps, which can take values 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

**property current_ac_resolution**
An property that controls the resolution in the AC current readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**property current_auto_range**
A boolean property that toggles auto ranging for DC current.

**property current_range**
A property that controls the DC current range in Amps, which can take values 100E-6, 1E-3, 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

**property current_resolution**
A property that controls the resolution in the DC current readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", and "DEF" (3.00E-5).

**property diode**
Reads a diode measurement in Volts, based on the active `mode`.

**property frequency**
Reads a frequency measurement in Hz, based on the active `mode`.

**property frequency_aperture**
A property that controls the frequency aperture in seconds, which sets the integration period and measurement speed. Takes values 100 ms, 1 s, as well as "MIN", "MAX", or "DEF" (1 s).

**property frequency_current_auto_range**
Boolean property that toggles auto ranging for AC current in frequency measurements.

**property frequency_current_range**
A property that controls the current range in Amps for frequency on AC current measurements, which can take values 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

**property frequency_voltage_auto_range**
Boolean property that toggles auto ranging for AC voltage in frequency measurements.

**property frequency_voltage_range**
A property that controls the voltage range in Volts for frequency on AC voltage measurements, which can take values 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

**property resistance**
Reads a resistance measurement in Ohms for 2-wire configuration, based on the active `mode`.

**property resistance_4w**
Reads a resistance measurement in Ohms for 4-wire configuration, based on the active `mode`.

**property resistance_4w_auto_range**
A boolean property that toggles auto ranging for 4-wire resistance.

**property resistance_4w_range**
A property that controls the 4-wire resistance range in Ohms, which can take values 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", or "DEF" (1E3). Auto-range is disabled when this property is set.

**property resistance_4w_resolution**
A property that controls the resolution in the 4-wire resistance readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**property resistance_auto_range**
A boolean property that toggles auto ranging for 2-wire resistance.

**property resistance_range**
A property that controls the 2-wire resistance range in Ohms, which can take values 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", or "DEF" (1E3). Auto-range is disabled when this property is set.

**property resistance_resolution**
A property that controls the resolution in the 2-wire resistance readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**property temperature**
Reads a temperature measurement in Celsius, based on the active `mode`.

**property voltage**
Reads a DC voltage measurement in Volts, based on the active `mode`.

**property voltage_ac**
Reads an AC voltage measurement in Volts, based on the active `mode`.

**property voltage_ac_auto_range**
A boolean property that toggles auto ranging for AC voltage.

**property voltage_ac_range**
A property that controls the AC voltage range in Volts, which can take values 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

**property voltage_ac_resolution**
A property that controls the resolution in the AC voltage readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

**property voltage_auto_range**
A boolean property that toggles auto ranging for DC voltage.

**property voltage_range**
A property that controls the DC voltage range in Volts, which can take values 100E-3, 1, 10, 100, 1000, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

**property voltage_resolution**
A property that controls the resolution in the DC voltage readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

### 7.6.7 Agilent 4155/4156 Semiconductor Parameter Analyzer

**class** pymeasure.instruments.agilent.agilent4156.**Agilent4156**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 4155/4156 Semiconductor Parameter Analyzer and provides a high-level interface for taking current-voltage (I-V) measurements.

```
from pymeasure.instruments.agilent import Agilent4156

# explicitly define r/w terminations; set sufficiently large timeout or None.
smu = Agilent4156("GPIB0::25", read_termination = '\n', write_termination = '\n',
                  timeout=None)

# reset the instrument
smu.reset()

# define configuration file for instrument and load config
smu.configure("configuration_file.json")

# save data variables, some or all of which are defined in the json config file.
smu.save(['VC', 'IC', 'VB', 'IB'])
```

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```
# take measurements
status = smu.measure()

# measured data is a pandas dataframe and can be exported to csv.
data = smu.get_data(path='./t1.csv')
```

The JSON file is an ascii text configuration file that defines the settings of each channel on the instrument. The JSON file is used to configure the instrument using the convenience function `configure()` as shown in the example above. For example, the instrument setup for a bipolar transistor measurement is shown below.

```
{
       "SMU1": {
           "voltage_name" : "VC",
           "current_name" : "IC",
           "channel_function" : "VAR1",
           "channel_mode" : "V",
           "series_resistance" : "0OHM"
       },

       "SMU2": {
           "voltage_name" : "VB",
           "current_name" : "IB",
           "channel_function" : "VAR2",
           "channel_mode" : "I",
           "series_resistance" : "0OHM"
       },

       "SMU3": {
           "voltage_name" : "VE",
           "current_name" : "IE",
           "channel_function" : "CONS",
           "channel_mode" : "V",
           "constant_value" : 0,
           "compliance" : 0.1
       },

        "SMU4": {
           "voltage_name" : "VS",
           "current_name" : "IS",
           "channel_function" : "CONS",
           "channel_mode" : "V",
           "constant_value" : 0,
           "compliance" : 0.1
       },

       "VAR1": {
           "start" : 1,
           "stop" : 2,
           "step" : 0.1,
           "spacing" : "LINEAR",
           "compliance" : 0.1
```

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```
        },

        "VAR2": {
            "start" : 0,
            "step" : 10e-6,
            "points" : 3,
            "compliance" : 2

        }
    }
```

**property analyzer_mode**

A string property that controls the instrument operating mode.

- Values: SWEEP, SAMPLING

```
smu.analyzer_mode = "SWEEP"
```

**configure**(*config_file*)

Configure the channel setup and sweep using a JSON configuration file.

(JSON is the JavaScript Object Notation)

**Parameters** **config_file** – JSON file to configure instrument channels.

```
instr.configure('config.json')
```

**property data_variables**

Get a string list of data variables for which measured data is available.

This looks for all the variables saved by the *save()* and *save_var()* methods and returns it. This is useful for creation of dataframe headers.

**Returns** List

```
header = instr.data_variables
```

**property delay_time**

A floating point property that measurement delay time in seconds, which can take the values from 0 to 65s in 0.1s steps.

```
instr.delay_time = 1 # delay time of 1-sec
```

**disable_all**()

Disables all channels in the instrument.

```
instr.disable_all()
```

**get_data**(*path=None*)

Get the measurement data from the instrument after completion.

If the measurement period is set to INF in the *measure()* method, then the measurement must be stopped using *stop()* before getting valid data.

**Parameters** **path** – Path for optional data export to CSV.

**Returns** Pandas Dataframe

```
df = instr.get_data(path='./datafolder/data1.csv')
```

**property hold_time**
A floating point property that measurement hold time in seconds, which can take the values from 0 to 655s in 1s steps.

```
instr.hold_time = 2 # hold time of 2-secs.
```

**property integration_time**
A string property that controls the integration time.

- Values: `SHORT`, `MEDIUM`, `LONG`

```
instr.integration_time = "MEDIUM"
```

**measure**(*period='INF'*, *points=100*)
Performs a single measurement and waits for completion in sweep mode. In sampling mode, the measurement period and number of points can be specified.

**Parameters**

- **period** – Period of sampling measurement from 6E-6 to 1E11 seconds. Default setting is `INF`.
- **points** – Number of samples to be measured, from 1 to 10001. Default setting is `100`.

**save**(*trace_list*)
Save the voltage or current in the instrument display list

**Parameters** **trace_list** – A list of channel variables whose measured data should be saved. A maximum of 8 variables are allowed. If only one variable is being saved, a string can be specified.

```
instr.save(['IC', 'IB', 'VC', 'VB']) #for list of variables
instr.save('IC')     #for single variable
```

**save_var**(*trace_list*)
Save the voltage or current in the instrument variable list.

This is useful if one or two more variables need to be saved in addition to the 8 variables allowed by *save()*.

**Parameters** **trace_list** – A list of channel variables whose measured data should be saved. A maximum of 2 variables are allowed. If only one variable is being saved, a string can be specified.

```
instr.save_var(['VA', 'VB'])
```

**stop**()
Stops the ongoing measurement

```
instr.stop()
```

**class** pymeasure.instruments.agilent.agilent4156.**SMU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

**property channel_function**
A string property that controls the SMU<n> channel function.

- Values: `VAR1`, `VAR2`, `VARD` or `CONS`.

```
instr.smu1.channel_function = "VAR1"
```

**property channel_mode**

A string property that controls the SMU<n> channel mode.

- Values: `V`, `I` or `COMM`

VPULSE AND IPULSE are not yet supported.

```
instr.smu1.channel_mode = "V"
```

**property compliance**

Sets the *constant* compliance value of SMU<n>.

If the SMU channel is setup as a variable (VAR1, VAR2, VARD) then compliance limits are set by the variable definition.

- Value: Voltage in (-200V, 200V) and current in (-1A, 1A) based on *channel_mode()*.

```
instr.smu1.compliance = 0.1
```

**property constant_value**

Set the constant source value of SMU<n>.

You use this command only if *channel_function()* is `CONS` and also *channel_mode()* should not be `COMM`.

**Parameters** **const_value** – Voltage in (-200V, 200V) and current in (-1A, 1A). Voltage or current depends on if *channel_mode()* is set to `V` or `I`.

```
instr.smu1.constant_value = 1
```

**property current_name**

Define the current name of the channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.smu1.current_name = "Ibase"
```

**property disable**

Deletes the settings of SMU<n>.

```
instr.smu1.disable()
```

**property series_resistance**

Controls the series resistance of SMU<n>.

- Values: `0OHM`, `10KOHM`, `100KOHM`, or `1MOHM`

```
instr.smu1.series_resistance = "10KOHM"
```

**property voltage_name**

Define the voltage name of the channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.smu1.voltage_name = "Vbase"
```

**class** pymeasure.instruments.agilent.agilent4156.**VAR1**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.agilent.agilent4156.VARX*

Class to handle all the specific definitions needed for VAR1. Most common methods are inherited from base class.

**property spacing**

Selects the sweep type of VAR1.

- Values: LINEAR, LOG10, LOG25, LOG50.

**class** pymeasure.instruments.agilent.agilent4156.**VAR2**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.agilent.agilent4156.VARX*

Class to handle all the specific definitions needed for VAR2. Common methods are imported from base class.

**property points**

Sets the number of sweep steps of VAR2. You use this command only if there is an SMU or VSU whose function (FCTN) is VAR2.

```
instr.var2.points = 10
```

**class** pymeasure.instruments.agilent.agilent4156.**VARD**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Class to handle all the definitions needed for VARD. VARD is always defined in relation to VAR1.

**property compliance**

Sets the sweep COMPLIANCE value of VARD.

```
instr.vard.compliance = 0.1
```

**property offset**

Sets the OFFSET value of VARD. For each step of sweep, the output values of VAR1' are determined by the following equation: VARD = VAR1 X RATio + OFFSet You use this command only if there is an SMU or VSU whose function is VARD.

```
instr.vard.offset = 1
```

**property ratio**

Sets the RATIO of VAR1'. For each step of sweep, the output values of VAR1' are determined by the following equation: VAR1' = VAR1 * RATio + OFFSet You use this command only if there is an SMU or VSU whose function (FCTN) is VAR1'.

```
instr.vard.ratio = 1
```

**class** pymeasure.instruments.agilent.agilent4156.**VARX**(*resourceName*, *var_name*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Base class to define sweep variable settings

**property compliance**

Sets the sweep COMPLIANCE value.

```
instr.var1.compliance = 0.1
```

**property start**

Sets the sweep START value.

```
instr.var1.start = 0
```

**property step**
Sets the sweep STEP value.

```
instr.var1.step = 0.1
```

**property stop**
Sets the sweep STOP value.

```
instr.var1.stop = 3
```

**class** pymeasure.instruments.agilent.agilent4156.**VMU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

**property channel_mode**
A string property that controls the VMU<n> channel mode.

- Values: V, DVOL

**property disable**
Disables the settings of VMU<n>.

```
instr.vmu1.disable()
```

**property voltage_name**
Define the voltage name of the VMU channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.vmu1.voltage_name = "Vanode"
```

**class** pymeasure.instruments.agilent.agilent4156.**VSU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

**property channel_function**
A string property that controls the VSU channel function.

- Value: VAR1, VAR2, VARD or CONS.

**property channel_mode**
Get channel mode of VSU<n>.

**property constant_value**
Sets the constant source value of VSU<n>.

```
instr.vsu1.constant_value = 0
```

**property disable**
Deletes the settings of VSU<n>.

```
instr.vsu1.disable()
```

**property voltage_name**
Define the voltage name of the VSU channel

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.vsu1.voltage_name = "Ve"
```

### 7.6.8 Agilent 33220A Arbitrary Waveform Generator

**class** pymeasure.instruments.agilent.**Agilent33220A**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 33220A Arbitrary Waveform Generator.

```
# Default channel for the Agilent 33220A
wfg = Agilent33220A("GPIB::10")

wfg.shape = "SINUSOID"          # Sets a sine waveform
wfg.frequency = 4.7e3           # Sets the frequency to 4.7 kHz
wfg.amplitude = 1               # Set amplitude of 1 V
wfg.offset = 0                  # Set the amplitude to 0 V

wfg.burst_state = True          # Enable burst mode
wfg.burst_ncycles = 10          # A burst will consist of 10 cycles
wfg.burst_mode = "TRIGGERED"    # A burst will be applied on a trigger
wfg.trigger_source = "BUS"      # A burst will be triggered on TRG*

wfg.output = True               # Enable output of waveform generator
wfg.trigger()                   # Trigger a burst
wfg.wait_for_trigger()          # Wait until the triggering is finished
wfg.beep()                      # "beep"

print(wfg.check_errors())       # Get the error queue
```

**property amplitude**

A floating point property that controls the voltage amplitude of the output waveform in V, from 10e-3 V to 10 V. Can be set.

**property amplitude_unit**

A string property that controls the units of the amplitude. Valid values are Vpp (default), Vrms, and dBm. Can be set.

**beep()**

Causes a system beep.

**property beeper_state**

A boolean property that controls the state of the beeper. Can be set.

**property burst_mode**

A string property that controls the burst mode. Valid values are: TRIG<GERED>, GAT<ED>. This setting can be set.

**property burst_ncycles**

An integer property that sets the number of cycles to be output when a burst is triggered. Valid values are 1 to 50000. This can be set.

**property burst_state**

A boolean property that controls whether the burst mode is on (True) or off (False). Can be set.

**property frequency**

A floating point property that controls the frequency of the output waveform in Hz, from 1e-6 (1 uHz) to

20e+6 (20 MHz), depending on the specified function. Can be set.

`property offset`
A floating point property that controls the voltage offset of the output waveform in V, from 0 V to 4.995 V, depending on the set voltage amplitude (maximum offset = (10 - voltage) / 2). Can be set.

`property output`
A boolean property that turns on (True) or off (False) the output of the function generator. Can be set.

`property pulse_dutycycle`
A floating point property that controls the duty cycle of a pulse waveform function in percent. Can be set.

`property pulse_hold`
A string property that controls if either the pulse width or the duty cycle is retained when changing the period or frequency of the waveform. Can be set to: WIDT<H> or DCYC<LE>.

`property pulse_period`
A floating point property that controls the period of a pulse waveform function in seconds, ranging from 200 ns to 2000 s. Can be set and overwrites the frequency for *all* waveforms. If the period is shorter than the pulse width + the edge time, the edge time and pulse width will be adjusted accordingly.

`property pulse_transition`
A floating point property that controls the the edge time in seconds for both the rising and falling edges. It is defined as the time between 0.1 and 0.9 of the threshold. Valid values are between 5 ns to 100 ns. The transition time has to be smaller than 0.625 * the pulse width. Can be set.

`property pulse_width`
A floating point property that controls the width of a pulse waveform function in seconds, ranging from 20 ns to 2000 s, within a set of restrictions depending on the period. Can be set.

`property ramp_symmetry`
A floating point property that controls the symmetry percentage for the ramp waveform. Can be set.

`property remote_local_state`
A string property that controls the remote/local state of the function generator. Valid values are: LOC<AL>, REM<OTE>, RWL<OCK>. This setting can only be set.

`property shape`
A string property that controls the output waveform. Can be set to: SIN<USOID>, SQU<ARE>, RAMP, PULS<E>, NOIS<E>, DC, USER.

`property square_dutycycle`
A floating point property that controls the duty cycle of a square waveform function in percent. Can be set.

`trigger()`
Send a trigger signal to the function generator.

`property trigger_source`
A string property that controls the trigger source. Valid values are: IMM<EDIATE> (internal), EXT<ERNAL> (rear input), BUS (via trigger command). This setting can be set.

`property trigger_state`
A boolean property that controls whether the output is triggered (True) or not (False). Can be set.

`property voltage_high`
A floating point property that controls the upper voltage of the output waveform in V, from -4.990 V to 5 V (must be higher than low voltage). Can be set.

`property voltage_low`
A floating point property that controls the lower voltage of the output waveform in V, from -5 V to 4.990 V (must be lower than high voltage). Can be set.

**wait_for_trigger**(*timeout=3600*, *should_stop=<function Agilent33220A.<lambda>>*)
Wait until the triggering has finished or timeout is reached.

**Parameters**

- **timeout** – The maximum time the waiting is allowed to take. If timeout is exceeded, a TimeoutError is raised. If timeout is set to zero, no timeout will be used.
- **should_stop** – Optional function (returning a bool) to allow the waiting to be stopped before its end.

### 7.6.9 Agilent 33500 Function/Arbitrary Waveform Generator Family

**class** pymeasure.instruments.agilent.**Agilent33500**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 33500 Function/Arbitrary Waveform Generator family. Individual devices are represented by subclasses.

```
generator = Agilent33500("GPIB::1")

generator.shape = 'SIN'                 # Sets the output signal shape to sine
generator.frequency = 1e3               # Sets the output frequency to 1 kHz
generator.amplitude = 5                 # Sets the output amplitude to 5 Vpp
generator.output = 'on'                 # Enables the output

generator.shape = 'ARB'                 # Set shape to arbitrary
generator.arb_srate = 1e6               # Set sample rate to 1MSa/s

generator.data_volatile_clear()         # Clear volatile internal memory
generator.data_arb(                     # Send data points of arbitrary waveform
    'test',
    range(-10000, 10000, +20),          # In this case a simple ramp
    data_format='DAC'                   # Data format is set to 'DAC'
)
generator.arb_file = 'test'             # Select the transmitted waveform 'test'
```

**property amplitude**
A floating point property that controls the voltage amplitude of the output waveform in V, from 10e-3 V to 10 V. Depends on the output impedance. Can be set.

**property amplitude_unit**
A string property that controls the units of the amplitude. Valid values are VPP (default), VRMS, and DBM. Can be set.

**property arb_advance**
A string property that selects how the device advances from data point to data point. Can be set to ‘TRIG<GER>’ or ‘SRAT<E>’ (default).

**property arb_file**
A string property that selects the arbitrary signal from the volatile memory of the device. String has to match an existing arb signal in volatile memore (set by data_arb()). Can be set.

**property arb_filter**
A string property that selects the filter setting for arbitrary signals. Can be set to ‘NORM<AL>’, ‘STEP’ and ‘OFF’.

**property arb_srate**
An floating point property that sets the sample rate of the currently selected arbitrary signal. Valid values are 1 µSa/s to 250 MSa/s (maximum range, can be lower depending on your device). This can be set.

**beep()**
Causes a system beep.

**property burst_mode**
A string property that controls the burst mode. Valid values are: TRIG<GERED>, GAT<ED>. This setting can be set.

**property burst_ncycles**
An integer property that sets the number of cycles to be output when a burst is triggered. Valid values are 1 to 100000. This can be set.

**property burst_period**
A floating point property that controls the period of subsequent bursts. Has to follow the equation burst_period > (burst_ncycles / frequency) + 1 µs. Valid values are 1 µs to 8000 s. Can be set.

**property burst_state**
A boolean property that controls whether the burst mode is on (True) or off (False). Can be set.

**clear_display()**
Removes a text message from the display.

**data_arb**(*arb_name*, *data_points*, *data_format='DAC'*)
Uploads an arbitrary trace into the volatile memory of the device. The data_points can be given as comma separated 16 bit DAC values (ranging from -32767 to +32767), as comma separated floating point values (ranging from -1.0 to +1.0) or as a binary data stream. Check the manual for more information. The storage depends on the device type and ranges from 8 Sa to 16 MSa (maximum). TODO: *Binary is not yet implemented*

**Parameters**

- **arb_name** – The name of the trace in the volatile memory. This is used to access the trace.
- **data_points** – Individual points of the trace. The format depends on the format parameter.

  format = 'DAC' (default): Accepts list of integer values ranging from -32767 to +32767. Minimum of 8 a maximum of 65536 points.

  format = 'float': Accepts list of floating point values ranging from -1.0 to +1.0. Minimum of 8 a maximum of 65536 points.

  format = 'binary': Accepts a binary stream of 8 bit data.
- **data_format** – Defines the format of data_points. Can be 'DAC' (default), 'float' or 'binary'. See documentation on parameter data_points above.

**data_volatile_clear()**
Clear all arbitrary signals from the volatile memory. This should be done if the same name is used continuously to load different arbitrary signals into the memory, since an error will occur if a trace is loaded which already exists in the memory.

**property display**
A string property which is displayed on the front panel of the device. Can be set.

**property ext_trig_out**
A boolean property that controls whether the trigger out signal is active (True) or not (False). This signal is output from the Ext Trig connector on the rear panel in Burst and Wobbel mode. Can be set.

**property frequency**
A floating point property that controls the frequency of the output waveform in Hz, from 1 uHz to 120 MHz (maximum range, can be lower depending on your device), depending on the specified function. Can be set.

**property id**
Reads the instrument identification

**property offset**
A floating point property that controls the voltage offset of the output waveform in V, from 0 V to 4.995 V, depending on the set voltage amplitude (maximum offset = (Vmax - voltage) / 2). Can be set.

**property output**
A boolean property that turns on (True, 'on') or off (False, 'off') the output of the function generator. Can be set.

**property output_load**
Sets the expected load resistance (should be the load impedance connected to the output. The output impedance is always 50 Ohm, this setting can be used to correct the displayed voltage for loads unmatched to 50 Ohm. Valid values are between 1 and 10 kOhm or INF for high impedance. No validator is used since both numeric and string inputs are accepted, thus a value outside the range will not return an error. Can be set.

**property phase**
A floating point property that controls the phase of the output waveform in degrees, from -360 degrees to 360 degrees. Not available for arbitrary waveforms or noise. Can be set.

**property pulse_dutycycle**
A floating point property that controls the duty cycle of a pulse waveform function in percent, from 0% to 100%. Can be set.

**property pulse_hold**
A string property that controls if either the pulse width or the duty cycle is retained when changing the period or frequency of the waveform. Can be set to: WIDT<H> or DCYC<LE>.

**property pulse_period**
A floating point property that controls the period of a pulse waveform function in seconds, ranging from 33 ns to 1e6 s. Can be set and overwrites the frequency for *all* waveforms. If the period is shorter than the pulse width + the edge time, the edge time and pulse width will be adjusted accordingly.

**property pulse_transition**
A floating point property that controls the edge time in seconds for both the rising and falling edges. It is defined as the time between the 10% and 90% thresholds of the edge. Valid values are between 8.4 ns to 1 µs. Can be set.

**property pulse_width**
A floating point property that controls the width of a pulse waveform function in seconds, ranging from 16 ns to 1e6 s, within a set of restrictions depending on the period. Can be set.

**property ramp_symmetry**
A floating point property that controls the symmetry percentage for the ramp waveform, from 0.0% to 100.0% Can be set.

**property shape**
A string property that controls the output waveform. Can be set to: SIN<USOID>, SQU<ARE>, TRI<ANGLE>, RAMP, PULS<E>, PRBS, NOIS<E>, ARB, DC.

**property square_dutycycle**
A floating point property that controls the duty cycle of a square waveform function in percent, from 0.01%

to 99.98%. The duty cycle is limited by the frequency and the minimal pulse width of 16 ns. See manual for more details. Can be set.

**trigger**()
Send a trigger signal to the function generator.

property **trigger_source**
A string property that controls the trigger source. Valid values are: IMM<EDIATE> (internal), EXT<ERNAL> (rear input), BUS (via trigger command). This setting can be set.

property **voltage_high**
A floating point property that controls the upper voltage of the output waveform in V, from -4.990 V to 5 V (must be higher than low voltage by at least 1 mV). Can be set.

property **voltage_low**
A floating point property that controls the lower voltage of the output waveform in V, from -5 V to 4.990 V (must be lower than high voltage by at least 1 mV). Can be set.

**wait_for_trigger**(*timeout=3600*, *should_stop=<function Agilent33500.<lambda>>*)
Wait until the triggering has finished or timeout is reached.

**Parameters**

- **timeout** – The maximum time the waiting is allowed to take. If timeout is exceeded, a TimeoutError is raised. If timeout is set to zero, no timeout will be used.
- **should_stop** – Optional function (returning a bool) to allow the waiting to be stopped before its end.

### 7.6.10 Agilent 33521A Function/Arbitrary Waveform Generator

class pymeasure.instruments.agilent.**Agilent33521A**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.agilent.agilent33500.Agilent33500*

Represents the Agilent 33521A Function/Arbitrary Waveform Generator.

This documentation page shows only methods different from the parent class *Agilent33500*.

property **arb_srate**
An floating point property that sets the sample rate of the currently selected arbitrary signal. Valid values are 1 µSa/s to 250 MSa/s. This can be set.

property **frequency**
A floating point property that controls the frequency of the output waveform in Hz, from 1 uHz to 30 MHz, depending on the specified function. Can be set.

### 7.6.11 Agilent B1500 Semiconductor Parameter Analyzer

**Contents**

### General Information

This instrument driver does not support all configuration options of the B1500 mainframe yet. So far, it is possible to interface multiple SMU modules and source/measure currents and voltages, perform sampling and staircase sweep measurements. The implementation of further measurement functionalities is highly encouraged. Meanwhile the model is managed by Keysight, see the corresponding "Programming Guide" for details on the control methods and their parameters

### Command Translation

Alphabetical list of implemented B1500 commands and their corresponding method/attribute names in this instrument driver.

| Command | Property/Method |
|---|---|
| `AAD` | *SMU.adc_type()* |
| `AB` | *abort()* |
| `AIT` | *adc_setup()* |
| `AV` | *adc_averaging()* |
| `AZ` | *adc_auto_zero* |
| `BC` | *clear_buffer()* |
| `CL` | *SMU.disable()* |
| `CM` | *auto_calibration* |
| `CMM` | *SMU.meas_op_mode()* |
| `CN` | *SMU.enable()* |
| `DI` | *SMU.force()* mode: `'CURRENT'` |
| `DV` | *SMU.force()* mode: `'VOLTAGE'` |
| `DZ` | *force_gnd()*, *SMU.force_gnd()* |
| `ERRX?` | *check_errors()* |
| `FL` | *SMU.filter* |
| `FMT` | *data_format()* |
| `*IDN?` | `id()` |
| `*LRN?` | *query_learn()*, multiple methods to read/format settings directly |
| `MI` | *SMU.sampling_source()* mode: `'CURRENT'` |
| `ML` | *sampling_mode* |
| `MM` | *meas_mode()* |
| `MSC` | *sampling_auto_abort()* |
| `MT` | *sampling_timing()* |
| `MV` | *SMU.sampling_source()* mode: `'VOLTAGE'` |
| `*OPC?` | *check_idle()* |
| `PA` | *pause()* |

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Table 1 – continued from previous page

| Command | Property/Method |
|---|---|
| PAD | *parallel_meas* |
| RI | *meas_range_current* |
| RM | *SMU.meas_range_current_auto()* |
| *RST | *reset()* |
| RV | *meas_range_voltage* |
| SSR | *series_resistor* |
| TSC | *time_stamp* |
| TSR | *clear_timer()* |
| UNT? | *query_modules()* |
| WAT | *wait_time()* |
| WI | *SMU.staircase_sweep_source()* mode: 'CURRENT' |
| WM | *sweep_auto_abort()* |
| WSI | *SMU.synchronous_sweep_source()* mode: 'CURRENT' |
| WSV | *SMU.synchronous_sweep_source()* mode: 'VOLTAGE' |
| WT | *sweep_timing()* |
| WV | *SMU.staircase_sweep_source()* mode: 'VOLTAGE' |
| XE | *send_trigger()* |

### Examples

#### Initialization of the Instrument

```
from pymeasure.instruments.agilent import AgilentB1500

# explicitly define r/w terminations; set sufficiently large timeout in milliseconds or␣
↪None.
b1500=AgilentB1500("GPIB0::17::INSTR", read_termination='\r\n', write_termination='\r\n',
↪ timeout=600000)
# query SMU config from instrument and initialize all SMU instances
b1500.initialize_all_smus()
# set data output format (required!)
b1500.data_format(21, mode=1) #call after SMUs are initialized to get names for the␣
↪channels
```

#### IV measurement with 4 SMUs

```
# choose measurement mode
b1500.meas_mode('STAIRCASE_SWEEP', *b1500.smu_references) #order in smu_references␣
↪determines order of measurement

# settings for individual SMUs
for smu in b1500.smu_references:
    smu.enable() #enable SMU
    smu.adc_type = 'HRADC' #set ADC to high-resoultion ADC
    smu.meas_range_current = '1 nA'
    smu.meas_op_mode = 'COMPLIANCE_SIDE' # other choices: Current, Voltage, FORCE_SIDE,␣
↪COMPLIANCE_AND_FORCE_SIDE
```

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```
# General Instrument Settings
# b1500.adc_averaging = 1
# b1500.adc_auto_zero = True
b1500.adc_setup('HRADC','AUTO',6)
#b1500.adc_setup('HRADC','PLC',1)

#Sweep Settings
b1500.sweep_timing(0,5,step_delay=0.1) #hold,delay
b1500.sweep_auto_abort(False,post='STOP') #disable auto abort, set post measurement␣
↪output condition to stop value of sweep
# Sweep Source
nop = 11
b1500.smu1.staircase_sweep_source('VOLTAGE','LINEAR_DOUBLE','Auto Ranging',0,1,nop,0.
↪001) #type, mode, range, start, stop, steps, compliance
# Synchronous Sweep Source
b1500.smu2.synchronous_sweep_source('VOLTAGE','Auto Ranging',0,1,0.001) #type, range,␣
↪start, stop, comp
# Constant Output (could also be done using synchronous sweep source with start=stop,␣
↪but then the output is not ramped up)
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3) #output␣
↪starts immediately! (compared to sweeps)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)

#Start Measurement
b1500.check_errors()
b1500.clear_buffer()
b1500.clear_timer()
b1500.send_trigger()

# read measurement data all at once
b1500.check_idle() #wait until measurement is finished
data = b1500.read_data(2*nop) #Factor 2 beacuse of double sweep

#alternatively: read measurement data live
meas = []
for i in range(nop*2):
    read_data = b1500.read_channels(4+1) # 4 measurement channels, 1 sweep source␣
↪(returned due to mode=1 of data_format)
    # process live data for plotting etc.
    # data format for every channel (status code, channel name e.g. 'SMU1', data name e.g
↪'Current Measurement (A)', value)
    meas.append(read_data)

#sweep constant sources back to 0V
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
```

### Sampling measurement with 4 SMUs

```
# choose measurement mode
b1500.meas_mode('SAMPLING', *b1500.smu_references) #order in smu_references determines␣
↪order of measurement
number_of_channels = len(b1500.smu_references)

# settings for individual SMUs
for smu in b1500.smu_references:
    smu.enable() #enable SMU
    smu.adc_type = 'HSADC' #set ADC to high-speed ADC
    smu.meas_range_current = '1 nA'
    smu.meas_op_mode = 'COMPLIANCE_SIDE' # other choices: Current, Voltage, FORCE_SIDE,␣
↪COMPLIANCE_AND_FORCE_SIDE

b1500.sampling_mode = 'LINEAR'
# b1500.adc_averaging = 1
# b1500.adc_auto_zero = True
b1500.adc_setup('HSADC','AUTO',1)
#b1500.adc_setup('HSADC','PLC',1)
nop=11
b1500.sampling_timing(2,0.005,nop) #MT: bias hold time, sampling interval, number of␣
↪points
b1500.sampling_auto_abort(False,post='BIAS') #MSC: BASE/BIAS
b1500.time_stamp = True

# Sources
b1500.smu1.sampling_source('VOLTAGE','Auto Ranging',0,1,0.001) #MV/MI: type, range, base,
↪ bias, compliance
b1500.smu2.sampling_source('VOLTAGE','Auto Ranging',0,1,0.001)
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3) #output␣
↪starts immediately! (compared to sweeps)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3)

#Start Measurement
b1500.check_errors()
b1500.clear_buffer()
b1500.clear_timer()
b1500.send_trigger()

meas=[]
for i in range(nop):
    read_data = b1500.read_channels(1+2*number_of_channels) #Sampling Index + (time␣
↪stamp + measurement value) * number of channels
    # process live data for plotting etc.
    # data format for every channel (status code, channel name e.g. 'SMU1', data name e.g
↪'Current Measurement (A)', value)
    meas.append(read_data)

#sweep constant sources back to 0V
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
```

### Main Classes

Classes to communicate with the instrument:

- `AgilentB1500`: Main instrument class
- `SMU`: Instantiated by main instrument class for every SMU

All *query* commands return a human readable dict of settings. These are intended for debugging/logging/file headers, not for passing to the accompanying setting commands.

**class** `pymeasure.instruments.agilent.agilentB1500.`**AgilentB1500**(*resourceName*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Agilent B1500 Semiconductor Parameter Analyzer and provides a high-level interface for taking different kinds of measurements.

**property smu_references**

Returns all SMU instances.

**property smu_names**

Returns all SMU names.

**query_learn**(*query_type*)

Queries settings from the instrument (`*LRN?`). Returns dict of settings.

**Parameters** **query_type** (`int or str`) – Query type (number according to manual)

**query_learn_header**(*query_type*, ***kwargs*)

Queries settings from the instrument (`*LRN?`). Returns dict of settings in human readable format for debugging or file headers. For optional arguments check the underlying definition of `QueryLearn.query_learn_header()`.

**Parameters** **query_type** (`int or str`) – Query type (number according to manual)

**reset**()

Resets the instrument to default settings (`*RST`)

**query_modules**()

Queries module models from the instrument. Returns dictionary of channel and module type.

**Returns** Channel:Module Type

**Return type** dict

**initialize_smu**(*channel*, *smu_type*, *name*)

Initializes SMU instance by calling `SMU`.

**Parameters**

- **channel** (`int`) – SMU channel
- **smu_type** (`str`) – SMU type, e.g. `'HRSMU'`
- **name** (`str`) – SMU name for pymeasure (data output etc.)

**Returns** SMU instance

**Return type** `SMU`

**initialize_all_smus**()

Initialize all SMUs by querying available modules and creating a SMU class instance for each. SMUs are accessible via attributes `.smu1` etc.

**pause**(*pause_seconds*)

Pauses Command Excecution for given time in seconds (`PA`)

**Parameters** **pause_seconds** (*int*) – Seconds to pause

**abort()**
Aborts the present operation but channels may still output current/voltage (AB)

**force_gnd()**
Force 0V on all channels immediately. Current Settings can be restored with RZ. (DZ)

**check_errors()**
Check for errors (ERRX?)

**check_idle()**
Check if instrument is idle (*OPC?)

**clear_buffer()**
Clear output data buffer (BC)

**clear_timer()**
Clear timer count (TSR)

**send_trigger()**
Send trigger to start measurement (except High Speed Spot) (XE)

**property auto_calibration**
Enable/Disable SMU auto-calibration every 30 minutes. (CM)

**Type** bool

**data_format**(*output_format*, *mode=0*)
Specifies data output format. Check Documentation for parameters. Should be called once per session to set the data format for interpreting the measurement values read from the instrument. (FMT)

Currently implemented are format 1, 11, and 21.

**Parameters**

- **output_format** (*str*) – Output format string, e.g. FMT21
- **mode** (*int, optional*) – Data output mode, defaults to 0 (only measurement data is returned)

**property parallel_meas**

**Enable/Disable parallel measurements.** Effective for SMUs using HSADC and measurement modes 1,2,10,18. (PAD)

**Type** bool

**query_meas_settings()**
Read settings for TM, AV, CM, FMT and MM commands (31) from the instrument.

**query_meas_mode()**
Read settings for MM command (part of 31) from the instrument.

**meas_mode**(*mode*, **args*)
Set Measurement mode of channels. Measurements will be taken in the same order as the SMU references are passed. (MM)

**Parameters**

- **mode** (*MeasMode*) – Measurement mode
  - Spot
  - Staircase Sweep

  - Sampling
- **args** (*SMU*) – SMU references

**query_adc_setup**()
Read ADC settings (55, 56) from the intrument.

**adc_setup**(*adc_type*, *mode*, *N=''*)
Set up operation mode and parameters of ADC for each ADC type. (AIT) Defaults:

- HSADC: Auto N=1, Manual N=1, PLC N=1, Time N=0.000002(s)
- HRADC: Auto N=6, Manual N=3, PLC N=1

**Parameters**

- **adc_type** (*ADCType*) – ADC type
- **mode** (*ADCMode*) – ADC mode
- **N** (*str, optional*) – additional parameter, check documentation, defaults to ''

**adc_averaging**(*number*, *mode='Auto'*)
Set number of averaging samples of the HSADC. (AV)

Defaults: N=1, Auto

**Parameters**

- **number** (*int*) – Number of averages
- **mode** (*AutoManual*, optional) – Mode ('Auto','Manual'), defaults to 'Auto'

**property adc_auto_zero**
Enable/Disable ADC zero function. Halfs the integration time, if off. (AZ)

**Type** bool

**property time_stamp**
Enable/Disable Time Stamp function. (TSC)

**Type** bool

**query_time_stamp_setting**()
Read time stamp settings (60) from the instrument.

**wait_time**(*wait_type*, *N*, *offset=0*)
Configure wait time. (WAT)

**Parameters**

- **wait_type** (*WaitTimeType*) – Wait time type
- **N** (*float*) – Coefficient for initial wait time, default: 1
- **offset** (*int, optional*) – Offset for wait time, defaults to 0

**query_staircase_sweep_settings**()
Reads Staircase Sweep Measurement settings (33) from the instrument.

**sweep_timing**(*hold*, *delay*, *step_delay=0*, *step_trigger_delay=0*, *measurement_trigger_delay=0*)
Sets Hold Time, Delay Time and Step Delay Time for staircase or multi channel sweep measurement. (WT) If not set, all parameters are 0.

**Parameters**

- **hold** (*float*) – Hold time

- **delay** (*float*) – Delay time
- **step_delay** (*float, optional*) – Step delay time, defaults to 0
- **step_trigger_delay** (*float, optional*) – Trigger delay time, defaults to 0
- **measurement_trigger_delay** (*float, optional*) – Measurement trigger delay time, defaults to 0

**sweep_auto_abort**(*abort*, *post='START'*)

Enables/Disables the automatic abort function. Also sets the post measurement condition. (`WM`)

**Parameters**

- **abort** (*bool*) – Enable/Disable automatic abort
- **post** (*StaircaseSweepPostOutput*, optional) – Output after measurement, defaults to 'Start'

**query_sampling_settings**()

Reads Sampling Measurement settings (47) from the instrument.

**property sampling_mode**

Set linear or logarithmic sampling mode. (`ML`)

**Type** *SamplingMode*

**sampling_timing**(*hold_bias*, *interval*, *number*, *hold_base=0*)

Sets Timing Parameters for the Sampling Measurement (`MT`)

**Parameters**

- **hold_bias** (*float*) – Bias hold time
- **interval** (*float*) – Sampling interval
- **number** (*int*) – Number of Samples
- **hold_base** (*float, optional*) – Base hold time, defaults to 0

**sampling_auto_abort**(*abort*, *post='Bias'*)

Enables/Disables the automatic abort function. Also sets the post measurement condition. (`MSC`)

**Parameters**

- **abort** (*bool*) – Enable/Disable automatic abort
- **post** (*SamplingPostOutput*, optional) – Output after measurement, defaults to 'Bias'

**read_data**(*number_of_points*)

Reads all data from buffer and returns Pandas DataFrame. Specify number of measurement points for correct splitting of the data list.

**Parameters** **number_of_points** (*int*) – Number of measurement points

**Returns** Measurement Data

**Return type** pd.DataFrame

**read_channels**(*nchannels*)

Reads data for 1 measurement point from the buffer. Specify number of measurement channels + sweep sources (depending on data output setting).

**Parameters** **nchannels** (*int*) – Number of channels which return data

**Returns** Measurement data

**Return type** tuple

**query_series_resistor**()
Read series resistor status (53) for all SMUs.

**query_meas_range_current_auto**()
Read auto ranging mode status (54) for all SMUs.

**query_meas_op_mode**()
Read SMU measurement operation mode (46) for all SMUs.

**query_meas_ranges**()
Read measruement ranging status (32) for all SMUs.

class pymeasure.instruments.agilent.agilentB1500.**SMU**(*parent*, *channel*, *smu_type*, *name*, ***kwargs*)
Bases: `object`

Provides specific methods for the SMUs of the Agilent B1500 mainframe

**Parameters**

- **parent** (*AgilentB1500*) – Instance of the B1500 mainframe class
- **channel** (*int*) – Channel number of the SMU
- **smu_type** (*str*) – Type of the SMU
- **name** (*str*) – Name of the SMU

**write**(*string*)
Wraps `Instrument.write()` method of B1500.

**ask**(*string*)
Wraps `ask()` method of B1500.

**query_learn**(*query_type*, *command*)
Wraps `query_learn()` method of B1500.

**check_errors**()
Wraps `check_errors()` method of B1500.

**property status**
Query status of the SMU.

**enable**()
Enable Source/Measurement Channel (`CN`)

**disable**()
Disable Source/Measurement Channel (`CL`)

**force_gnd**()
Force 0V immediately. Current Settings can be restored with `RZ` (not implemented). (`DZ`)

**property filter**
Enables/Disables SMU Filter. (`FL`)

**Type** bool

**property series_resistor**
Enables/Disables 1MOhm series resistor. (`SSR`)

**Type** bool

**property meas_op_mode**
Set SMU measurement operation mode. (`CMM`)

**Type** *MeasOpMode*

**property adc_type**
ADC type of individual measurement channel. (AAD)

**Type** *ADCType*

**force**(*source_type*, *source_range*, *output*, *comp=''*, *comp_polarity=''*, *comp_range=''*)
Applies DC Current or Voltage from SMU immediately. (DI, DV)

**Parameters**

- **source_type** (*str*) – Source type ('Voltage','Current')
- **source_range** (*int or str*) – Output range index or name
- **output** – Source output value in A or V
- **comp** (*float, optional*) – Compliance value, defaults to previous setting
- **comp_polarity** (*CompliancePolarity*) – Compliance polairty, defaults to auto
- **comp_range** (*int or str, optional*) – Compliance ranging type, defaults to auto

**ramp_source**(*source_type*, *source_range*, *target_output*, *comp=''*, *comp_polarity=''*, *comp_range=''*, *stepsize=0.001*, *pause=0.02*)
Ramps to a target output from the set value with a given step size, each separated by a pause.

**Parameters**

- **source_type** (*str*) – Source type ('Voltage' or 'Current')
- **target_output** – Target output voltage or current
- **irange** (*int*) – Output range index
- **comp** (*float, optional*) – Compliance, defaults to previous setting
- **comp_polarity** (*CompliancePolarity*) – Compliance polairty, defaults to auto
- **comp_range** (*int or str, optional*) – Compliance ranging type, defaults to auto
- **stepsize** – Maximum size of steps
- **pause** – Duration in seconds to wait between steps

**Type** target_output: float

**property meas_range_current**
Current measurement range index. (RI)

Possible settings depend on SMU type, e.g. 0 for Auto Ranging: *SMUCurrentRanging*

**property meas_range_voltage**
Voltage measurement range index. (RV)

Possible settings depend on SMU type, e.g. 0 for Auto Ranging: *SMUVoltageRanging*

**meas_range_current_auto**(*mode*, *rate=50*)
Specifies the auto range operation. Check Documentation. (RM)

**Parameters**

- **mode** (*int*) – Range changing operation mode
- **rate** (*int, optional*) – Parameter used to calculate the *current* value, defaults to 50

**staircase_sweep_source**(*source_type*, *mode*, *source_range*, *start*, *stop*, *steps*, *comp*, *Pcomp=''*)
Specifies Staircase Sweep Source (Current or Voltage) and its parameters. (WV or WI)

**Parameters**

- **source_type** (*str*) – Source type ('Voltage','Current')
- **mode** (*SweepMode*) – Sweep mode
- **source_range** (*int*) – Source range index
- **start** (*float*) – Sweep start value
- **stop** (*float*) – Sweep stop value
- **steps** (*int*) – Number of sweep steps
- **comp** (*float*) – Compliance value
- **Pcomp** (*float, optional*) – Power compliance, defaults to not set

**synchronous_sweep_source**(*source_type*, *source_range*, *start*, *stop*, *comp*, *Pcomp=''*)
Specifies Synchronous Staircase Sweep Source (Current or Voltage) and its parameters. (`WSV` or `WSI`)

**Parameters**

- **source_type** (*str*) – Source type ('Voltage','Current')
- **source_range** (*int*) – Source range index
- **start** (*float*) – Sweep start value
- **stop** (*float*) – Sweep stop value
- **comp** (*float*) – Compliance value
- **Pcomp** (*float, optional*) – Power compliance, defaults to not set

**sampling_source**(*source_type*, *source_range*, *base*, *bias*, *comp*)
Sets DC Source (Current or Voltage) for sampling measurement. DV/DI commands on the same channel overwrite this setting. (`MV` or `MI`)

**Parameters**

- **source_type** (*str*) – Source type ('Voltage','Current')
- **source_range** (*int*) – Source range index
- **base** (*float*) – Base voltage/current
- **bias** (*float*) – Bias voltage/current
- **comp** (*float*) – Compliance value

## Supporting Classes

Classes that provide additional functionalities:

- *QueryLearn*: Process read out of instrument settings
- *SMUCurrentRanging*, *SMUVoltageRanging*: Allowed ranges for different SMU types and transformation of range names to indices (base: *Ranging*)

**class** pymeasure.instruments.agilent.agilentB1500.**QueryLearn**
Bases: `object`

Methods to issue and process `*LRN?` (learn) command and response.

**static query_learn**(*ask*, *query_type*)
Issues `*LRN?` (learn) command to the instrument to read configuration. Returns dictionary of commands and set values.

**Parameters** **query_type** (*int*) – Query type according to the programming guide

**Returns** Dictionary of command and set values

**Return type** dict

**classmethod query_learn_header**(*ask*, *query_type*, *smu_references*, *single_command=False*)

Issues `*LRN?` (learn) command to the instrument to read configuration. Processes information to human readable values for debugging purposes or file headers.

**Parameters**

- **ask** (*Instrument.ask*) – ask method of the instrument
- **query_type** (*int or str*) – Number according to Programming Guide
- **smu_references** (*dict*) – SMU references by channel
- **single_command** (*str*) – if only a single command should be returned, defaults to False

**Returns** Read configuration

**Return type** dict

**static to_dict**(*parameters*, *names*, **args*)

Takes parameters returned by `query_learn()` and ordered list of corresponding parameter names (optional function) and returns dict of parameters including names.

**Parameters**

- **parameters** (*dict*) – Parameters for one command returned by `query_learn()`
- **names** (*list*) – list of names or (name, function) tuples, ordered

**Returns** Parameter name and (processed) parameter

**Return type** dict

**class** pymeasure.instruments.agilent.agilentB1500.**Ranging**(*supported_ranges*, *ranges*, *fixed_ranges=False*)

Bases: `object`

Possible Settings for SMU Current/Voltage Output/Measurement ranges. Transformation of available Voltage/Current Range Names to Index and back.

**Parameters**

- **supported_ranges** (*list*) – Ranges which are supported (list of range indizes)
- **ranges** (*dict*) – All range names `{Name:  Indizes}`
- **fixed_ranges** – add fixed ranges (negative indizes); defaults to False

**__call__**(*input_value*)

Gives named tuple (name/index) of given Range. Throws error if range is not supported by this SMU.

**Parameters** **input** (*str or int*) – Range name or index

**Returns** named tuple (name/index) of range

**Return type** namedtuple

**class** pymeasure.instruments.agilent.agilentB1500.**SMUCurrentRanging**(*smu_type*)

Bases: `object`

Provides Range Name/Index transformation for current measurement/sourcing. Validity of ranges is checked against the type of the SMU.

Omitting the 'limited auto ranging'/'range fixed' specification in the range string for current measurement defaults to 'limited auto ranging'.

Full specification: '1 nA range fixed' or '1 nA limited auto ranging'

'1 nA' defaults to '1 nA limited auto ranging'

**class pymeasure.instruments.agilent.agilentB1500.SMUVoltageRanging**(*smu_type*)

Bases: `object`

Provides Range Name/Index transformation for voltage measurement/sourcing. Validity of ranges is checked against the type of the SMU.

Omitting the 'limited auto ranging'/'range fixed' specification in the range string for voltage measurement defaults to 'limited auto ranging'.

Full specification: '2 V range fixed' or '2 V limited auto ranging'

'2 V' defaults to '2 V limited auto ranging'

### Enumerations

Enumerations are used for easy selection of the available parameters (where it is applicable). Methods accept member name or number as input, but name is recommended for readability reasons. The member number is passed to the instrument. Converting an enumeration member into a string gives a title case, whitespace separated string (`__str__()`) which cannot be used to select an enumeration member again. It's purpose is only logging or documentation.

**class pymeasure.instruments.agilent.agilentB1500.CustomIntEnum**(*value*)

Bases: `enum.IntEnum`

Provides additional methods to IntEnum:

- Conversion to string automatically replaces '_' with ' ' in names and converts to title case
- get classmethod to get enum reference with name or integer

**__str__**()

Gives title case string of enum value

**classmethod get**(*input_value*)

Gives Enum member by specifying name or value.

**Parameters** **input_value** (*str or int*) – Enum name or value

**Returns** Enum member

**class pymeasure.instruments.agilent.agilentB1500.ADCType**(*value*)

Bases: `pymeasure.instruments.agilent.agilentB1500.CustomIntEnum`

ADC Type

**HSADC = 0**

High-speed ADC

**HRADC = 1**

High-resolution ADC

**HSADC_PULSED = 2**

High-resolution ADC for pulsed measurements

**class pymeasure.instruments.agilent.agilentB1500.ADCMode**(*value*)

Bases: `pymeasure.instruments.agilent.agilentB1500.CustomIntEnum`

ADC Mode

**AUTO = 0**

**MANUAL = 1**

**PLC = 2**

**TIME = 3**

**class** pymeasure.instruments.agilent.agilentB1500.**AutoManual**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Auto/Manual selection

**AUTO = 0**

**MANUAL = 1**

**class** pymeasure.instruments.agilent.agilentB1500.**MeasMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Measurement Mode

**SPOT = 1**

**STAIRCASE_SWEEP = 2**

**SAMPLING = 10**

**class** pymeasure.instruments.agilent.agilentB1500.**MeasOpMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Measurement Operation Mode

**COMPLIANCE_SIDE = 0**

**CURRENT = 1**

**VOLTAGE = 2**

**FORCE_SIDE = 3**

**COMPLIANCE_AND_FORCE_SIDE = 4**

**class** pymeasure.instruments.agilent.agilentB1500.**SweepMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Sweep Mode

**LINEAR_SINGLE = 1**

**LOG_SINGLE = 2**

**LINEAR_DOUBLE = 3**

**LOG_DOUBLE = 4**

**class** pymeasure.instruments.agilent.agilentB1500.**SamplingMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Sampling Mode

**LINEAR = 1**

**LOG_10 = 2**
Logarithmic 10 data points/decade

**LOG_25 = 3**
Logarithmic 25 data points/decade

**LOG_50 = 4**
Logarithmic 50 data points/decade

**LOG_100 = 5**
Logarithmic 100 data points/decade

**LOG_250 = 6**
Logarithmic 250 data points/decade

**LOG_5000 = 7**
Logarithmic 5000 data points/decade

class pymeasure.instruments.agilent.agilentB1500.**SamplingPostOutput**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Output after sampling

**BASE = 1**

**BIAS = 2**

class pymeasure.instruments.agilent.agilentB1500.**StaircaseSweepPostOutput**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Output after staircase sweep

**START = 1**

**STOP = 2**

class pymeasure.instruments.agilent.agilentB1500.**CompliancePolarity**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Compliance polarity

**AUTO = 0**

**MANUAL = 1**

class pymeasure.instruments.agilent.agilentB1500.**WaitTimeType**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Wait time type

**SMU_SOURCE = 1**

**SMU_MEASUREMENT = 2**

**CMU_MEASUREMENT = 3**

## 7.7 Ametek

This section contains specific documentation on the Ametek instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.7.1 Ametek 7270 DSP Lockin Amplifier

**class** pymeasure.instruments.ametek.**Ametek7270**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

This is the class for the Ametek DSP 7270 lockin amplifier

**property adc1**
Reads the input value of ADC1 in Volts

**property adc2**
Reads the input value of ADC2 in Volts

**property adc3**
Reads the input value of ADC3 in Volts

**property adc4**
Reads the input value of ADC4 in Volts

**property dac1**
A floating point property that represents the output value on DAC1 in Volts. This property can be set.

**property dac2**
A floating point property that represents the output value on DAC2 in Volts. This property can be set.

**property dac3**
A floating point property that represents the output value on DAC3 in Volts. This property can be set.

**property dac4**
A floating point property that represents the output value on DAC4 in Volts. This property can be set.

**property frequency**
A floating point property that represents the lock-in frequency in Hz. This property can be set.

**property harmonic**
An integer property that represents the reference harmonic mode control, taking values from 1 to 127. This property can be set.

**property id**
Reads the instrument identification

**property mag**
Reads the magnitude in Volts

**property phase**
A floating point property that represents the reference harmonic phase in degrees. This property can be set.

**property sensitivity**
A floating point property that controls the sensitivity range in Volts, which can take discrete values from 2 nV to 1 V. This property can be set.

**set_channel_A_mode**()
Sets instrument to channel A mode – assuming it is in voltage mode

**set_differential_mode**(*lineFiltering=True*)
Sets instrument to differential mode – assuming it is in voltage mode

**set_voltage_mode**()
Sets instrument to voltage control mode

**shutdown**()
Ensures the instrument in a safe state

**property slope**
A integer property that controls the filter slope in dB/octave, which can take the values 6, 12, 18, or 24 dB/octave. This property can be set.

**property time_constant**
A floating point property that controls the time constant in seconds, which takes values from 10 microseconds to 100,000 seconds. This property can be set.

**property voltage**
A floating point property that represents the voltage in Volts. This property can be set.

**property x**
Reads the X value in Volts

**property x1**
Reads the first harmonic X value in Volts

**property x2**
Reads the second harmonic X value in Volts

**property xy**
Reads both the X and Y values in Volts

**property y**
Reads the Y value in Volts

**property y1**
Reads the first harmonic Y value in Volts

**property y2**
Reads the second harmonic Y value in Volts

## 7.8 AMI

This section contains specific documentation on the AMI instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.8.1 AMI 430 Power Supply

**class** pymeasure.instruments.ami.**AMI430**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the AMI 430 Power supply and provides a high-level for interacting with the instrument.

```
magnet = AMI430("TCPIP::web.address.com::7180::SOCKET")


magnet.coilconst = 1.182                 # kGauss/A
magnet.voltage_limit = 2.2               # Sets the voltage limit in V

magnet.target_current = 10               # Sets the target current to 10 A
magnet.target_field = 1                  # Sets target field to 1 kGauss

magnet.ramp_rate_current = 0.0357       # Sets the ramp rate in A/s
magnet.ramp_rate_field = 0.0422         # Sets the ramp rate in kGauss/s
magnet.ramp                             # Initiates the ramping
```

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```
magnet.pause                         # Pauses the ramping
magnet.status                        # Returns the status of the magnet

magnet.ramp_to_current(5)           # Ramps the current to 5 A

magnet.shutdown()                   # Ramps the current to zero and disables␣
↪output
```

**property coilconst**
A floating point property that sets the coil contant in kGauss/A.

**disable_persistent_switch()**
Disables the persistent switch.

**enable_persistent_switch()**
Enables the persistent switch.

**property field**
Reads the field in kGauss of the magnet.

**has_persistent_switch_enabled()**
Returns a boolean if the persistent switch is enabled.

**property magnet_current**
Reads the current in Amps of the magnet.

**pause()**
Pauses the ramping of the magnetic field.

**ramp()**
Initiates the ramping of the magnetic field to set current/field with ramping rate previously set.

**property ramp_rate_current**
A floating point property that sets the current ramping rate in A/s.

**property ramp_rate_field**
A floating point property that sets the field ramping rate in kGauss/s.

**ramp_to_current**(*current*, *rate*)
Heats up the persistent switch and ramps the current with set ramp rate.

**ramp_to_field**(*field*, *rate*)
Heats up the persistent switch and ramps the current with set ramp rate.

**shutdown**(*ramp_rate=0.0357*)
Turns on the persistent switch, ramps down the current to zero, and turns off the persistent switch.

**property state**
Reads the field in kGauss of the magnet.

**property supply_current**
Reads the current in Amps of the power supply.

**property target_current**
A floating point property that sets the target current in A for the magnet.

**property target_field**
A floating point property that sets the target field in kGauss for the magnet.

**property voltage_limit**
A floating point property that sets the voltage limit for charging/discharging the magnet.

**wait_for_holding**(*should_stop=<function AMI430.<lambda>>*, *timeout=800*, *interval=0.1*)

**zero**()
Initiates the ramping of the magnetic field to zero current/field with ramping rate previously set.

## 7.9 Anaheim Automation

This section contains specific documentation on the Anaheim Automation instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.9.1 DP-Series Step Motor Controller

The DPSeriesMotorController class implements a base driver class for Anaheim-Automation DP Series stepper motor controllers. There are many controllers sold in this series, all of which implement the same core command set. Some controllers, like the DPY50601, implement additional functionality that is not included in this driver. If these additional features are desired, they should be implemented in a subclass.

**class** pymeasure.instruments.anaheimautomation.**DPSeriesMotorController**(*resourceName*, *address=0*, *encoder_enabled=False*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Base class to interface with Anaheim Automation DP series stepper motor controllers.

This driver has been tested with the DPY50601 and DPE25601 motor controllers.

**property absolute_position**
Float property representing the value of the motor position measured in absolute units. Note that in DP series motor controller instrument manuals, *absolute position* refers to the 'step_position' property rather than this property. Also note that use of this property relies on steps_to_absolute() and absolute_to_steps() being implemented in a subclass. In this way, the user can define the conversion from a motor step position into any desired absolute unit. Absolute units could be the position in meters of a linear stage or the angular position of a gimbal mount, etc. This property can be set.

**absolute_to_steps**(*pos*)
Convert an absolute position to a number of steps to move. This must be implemented in subclasses.

**Parameters pos** – Absolute position in the units determined by the subclassed absolute_to_steps() method.

**property address**
Integer property representing the address that the motor controller uses for serial communications.

**ask**(*command*)
Override the instrument base ask method to add the motor controller's address to the command string.

**Parameters command** – command string to be sent to the instrument

**property basespeed**
Integer property that represents the motor controller's starting/homing speed. This property can be set.

**property busy**
Query to see if the controller is currently moving a motor.

**check_errors**()
Method to read the error codes register and log when an error is detected.

**Return error_code** one byte with the error codes register contents

**property direction**
A string property that represents the direction in which the stepper motor will rotate upon subsequent step commands. This property can be set. 'CW' corresponds to clockwise rotation and 'CCW' corresponds to counter-clockwise rotation.

**property encoder_autocorrect**
A boolean property to enable or disable the encoder auto correct function. This property can be set.

**property encoder_delay**
An integer property that represents the wait time in ms. after a move is finished before the encoder is read for a potential encoder auto-correct action to take place. This property can be set.

**property encoder_enabled**
A boolean property to represent whether an external encoder is connected and should be used to set the step_position property.

**property encoder_motor_ratio**
An integer property that represents the ratio of the number of encoder pulses per motor step. This property can be set.

**property encoder_retries**
An integer property that represents the number of times the motor controller will try the encoder auto correct function before setting an error flag. This property can be set.

**property encoder_window**
An integer property that represents the allowable error in encoder pulses from the desired position before the encoder auto-correct function runs. This property can be set.

**property error_reg**
Reads the current value of the error codes register.

**home**(*home_mode*)
Send command to the motor controller to 'home' the motor.

**Parameters** **home_mode** – 0 or 1 specifying which homing mode to run.

0 will perform a homing operation where the controller moves the motor until a soft limit is reached, then will ramp down to base speed and continue motion until a home limit is reached.

In mode 1, the controller will move the motor until a limit is reached, then will ramp down to base speed, change direction, and run until the limit is released.

**property maxspeed**
Integer property that represents the motor controller's maximum (running) speed. This property can be set.

**move**(*direction*)
Move the stepper motor continuously in the given direction until a stop command is sent or a limit switch is reached. This method corresponds to the 'slew' command in the DP series instrument manuals.

**Parameters** **direction** – value to set on the direction property before moving the motor.

**reset_position**()
Reset the position as counted by the motor controller and an externally connected encoder to 0.

**property step_position**
Integer property representing the value of the motor position measured in steps counted by the motor controller or, if encoder_enabled is set, the steps counted by an externally connected encoder. Note that in the DP series motor controller instrument manuals, this property would be referred to as the 'absolute position' while this driver implements a conversion between steps and absolute units for the *absolute position* property. This property can be set.

**steps_to_absolute**(*steps*)
Convert a position measured in steps to an absolute position.

**Parameters** **steps** – Position in steps to be converted to an absolute position.

**stop**()
Method that stops all motion on the motor controller.

**values**(*command*, ***kwargs*)
Override the instrument base values method to add the motor controller's address to the command string.

**Parameters** **command** – command string to be sent to the motor controller.

**wait_for_completion**(*interval=0.5*)
Block until the controller is not "busy" (i.e. block until the motor is no longer moving.)

**Parameters** **interval** – (float) seconds between queries to the "busy" flag.

**Returns** None

**write**(*command*)
Override the instrument base write method to add the motor controller's address to the command string.

**Parameters** **command** – command string to be sent to the motor controller.

## 7.10 Anapico

This section contains specific documentation on the Anapico instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.10.1 Anapico APSIN12G Signal Generator

class pymeasure.instruments.anapico.**APSIN12G**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Anapico APSIN12G Signal Generator with option 9K, HP and GPIB.

**property blanking**
A string property that represents the blanking of output power when frequency is changed. ON makes the output to be blanked (off) while changing frequency. This property can be set.

**disable_rf**()
Disables the RF output.

**enable_rf**()
Enables the RF output.

**property frequency**
A floating point property that represents the output frequency in Hz. This property can be set.

**property power**
A floating point property that represents the output power in dBm. This property can be set.

**property reference_output**
A string property that represents the 10MHz reference output from the synth. This property can be set.

## 7.11 Andeen Hagerling

This section contains specific documentation on the Andeen Hagerling instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.11.1 Andeen Hagerling AH2500A capacitance bridge

**class** `pymeasure.instruments.andeenhagerling.AH2500A`(*adapter*, *name=None*, *timeout=3000*, *write_termination='\n'*, *read_termination='\n'*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Andeen Hagerling 2500A Precision Capacitance Bridge implementation

**property caplossvolt**
Perform a single capacitance, loss measurement and return the values in units of pF and nS. The used measurement voltage is returned as third value.

**property config**
Read out configuration

**trigger()**
Triggers a new measurement without blocking and waiting for the return value.

**triggered_caplossvolt()**
reads the measurement value after the device was triggered by the trigger function.

**property vhighest**
maximum RMS value of the used measurement voltage. Values of up to 15 V are allowed. The device will select the best suiting range below the given value.

### 7.11.2 Andeen Hagerling AH2700A capacitance bridge

**class** `pymeasure.instruments.andeenhagerling.AH2700A`(*adapter*, *name='Andeen Hagerling 2700A Precision Capacitance Bridge'*, *timeout=5000*, ***kwargs*)

Bases: `pymeasure.instruments.andeenhagerling.ah2500a.AH2500A`

Andeen Hagerling 2700A Precision Capacitance Bridge implementation

**property caplossvolt**
Perform a single capacitance, loss measurement and return the values in units of pF and nS. The used measurement voltage is returned as third value.

**property config**
Read out configuration

**property frequency**
test frequency used for the measurements. Allowed are values between 50 and 20000 Hz. The device selects the closest possible frequency to the given value.

**property id**
Reads the instrument identification

**reset()**
Resets the instrument.

**trigger**()
Triggers a new measurement without blocking and waiting for the return value.

**triggered_caplossvolt**()
reads the measurement value after the device was triggered by the trigger function.

**property vhighest**
maximum RMS value of the used measurement voltage. Values of up to 15 V are allowed. The device will select the best suiting range below the given value.

## 7.12 Anritsu

This section contains specific documentation on the Anritsu instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.12.1 Anritsu MG3692C Signal Generator

**class** pymeasure.instruments.anritsu.**AnritsuMG3692C**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Anritsu MG3692C Signal Generator

**disable**()
Disables the signal output.

**enable**()
Enables the signal output.

**property frequency**
A floating point property that represents the output frequency in Hz. This property can be set.

**property output**
A boolean property that represents the signal output state. This property can be set to control the output.

**property power**
A floating point property that represents the output power in dBm. This property can be set.

**shutdown**()
Shuts down the instrument, putting it in a safe state.

### 7.12.2 Anritsu MS9710C Optical Spectrum Analyzer

**class** pymeasure.instruments.anritsu.**AnritsuMS9710C**(*adapter*, *name='Anritsu MS9710C Optical Spectrum Analyzer'*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Anritsu MS9710C Optical Spectrum Analyzer.

**property analysis**
Analysis Control

**property analysis_result**
Read back anaysis result from current scan.

**property average_point**
Number of averages to take on each point (2-1000), or OFF

**property average_sweep**
Number of averages to make on a sweep (2-1000) or OFF

**center_at_peak**(***kwargs*)
Center the spectrum at the measured peak.

**property data_memory_a_condition**
Returns the data condition of data memory register A. Starting wavelength, and a sampling point (l1, l2, n).

**property data_memory_a_size**
Returns the number of points sampled in data memory register A.

**property data_memory_a_values**
Reads the binary data from memory register A.

**property data_memory_b_condition**
Returns the data condition of data memory register B. Starting wavelength, and a sampling point (l1, l2, n).

**property data_memory_b_size**
Returns the number of points sampled in data memory register B.

**property data_memory_b_values**
Reads the binary data from memory register B.

**property data_memory_select**
Memory Data Select.

**property dip_search**
Dip Search Mode

**property ese2**
Extended Event Status Enable Register 2

**property esr2**
Extended Event Status Register 2

**property level_lin**
Level Linear Scale (/div)

**property level_log**
Level Log Scale (/div)

**property level_opt_attn**
Optical Attenuation Status (ON/OFF)

**property level_scale**
Current Level Scale

**property measure_mode**
Returns the current Measure Mode the OSA is in.

**measure_peak**()
Measure the peak and return the trace marker.

**property peak_search**
Peak Search Mode

**read_memory**(*slot='A'*)
Read the scan saved in a memory slot.

**property resolution**
Resolution (nm)

**property resolution_actual**
Resolution Actual (ON/OFF)

**property resolution_vbw**
Video Bandwidth Resolution

**property sampling_points**
Number of sampling points

**single_sweep**(***kwargs*)
Perform a single sweep and wait for completion.

**property trace_marker**
Sets the trace marker with a wavelength. Returns the trace wavelength and power.

**property trace_marker_center**
Trace Marker at Center. Set to 1 or True to initiate command

**wait**(*n=3*, *delay=1*)
Query OPC Command and waits for appropriate response.

**wait_for_sweep**(*n=20*, *delay=0.5*)
Wait for a sweep to stop.

This is performed by checking bit 1 of the ESR2.

**property wavelength_center**
Center Wavelength of Spectrum Scan in nm.

**property wavelength_marker_value**
Wavelength Marker Value (wavelength or freq.?)

**property wavelength_span**
Wavelength Span of Spectrum Scan in nm.

**property wavelength_start**
Wavelength Start of Spectrum Scan in nm.

**property wavelength_stop**
Wavelength Stop of Spectrum Scan in nm.

**property wavelength_value_in**
Wavelength value in Vacuum or Air

**property wavelengths**
Return a numpy array of the current wavelengths of scans.

### 7.12.3 Anritsu MS9740A Optical Spectrum Analyzer

**class** pymeasure.instruments.anritsu.**AnritsuMS9740A**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.anritsu.anritsuMS9710C.AnritsuMS9710C*

Anritsu MS9740A Optical Spectrum Analyzer.

**property average_sweep**
Nr. of averages to make on a sweep (1-1000), with 1 being a single (non-averaged) sweep

**property data_memory_select**
Memory Data Select.

**repeat_sweep**(*n=20*, *delay=0.5*)
Perform a single sweep and wait for completion.

**property resolution**
Resolution (nm)

**property resolution_vbw**
Video Bandwidth Resolution

**property sampling_points**
Number of sampling points

## 7.13 Attocube

This section contains specific documentation on the Attocube instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.13.1 Attocube Adapters

**class** pymeasure.instruments.attocube.adapters.**AttocubeConsoleAdapter**(*host*, *port*, *passwd*, ***kwargs*)

Bases: *pymeasure.adapters.telnet.TelnetAdapter*

Adapter class for connecting to the Attocube Standard Console. This console is a Telnet prompt with password authentication.

**Parameters**

- **host** – host address of the instrument
- **port** – TCPIP port
- **passwd** – password required to open the connection
- **kwargs** – Any valid key-word argument for TelnetAdapter

**ask**(*command*)
Writes a command to the instrument and returns the resulting ASCII response

**Parameters** **command** – command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**check_acknowledgement**(*reply*, *msg=''*)
checks the last reply of the instrument to be 'OK', otherwise a ValueError is raised.

**Parameters**

- **reply** – last reply string of the instrument
- **msg** – optional message for the eventual error

**extract_value**(*reply*)
preprocess_reply function for the Attocube console. This function tries to extract <value> from 'name = <value> [unit]'. If <value> can not be identified the original string is returned.

**Parameters** **reply** – reply string

**Returns** string with only the numerical value, or the original string

**read**()
Reads a reply of the instrument which consists of two or more lines. The first ones are the reply to the command while the last one is 'OK' or 'ERROR' to indicate any problem. In case the reply is not OK a ValueError is raised.

**Returns** String ASCII response of the instrument.

**write**(*command*, *check_ack=True*)
Writes a command to the instrument

**Parameters**

- **command** – command string to be sent to the instrument
- **check_ack** – boolean flag to decide if the acknowledgement is read back from the instrument. This should be True for set pure commands and False otherwise.

### 7.13.2 Attocube ANC300 Motion Controller

**class** pymeasure.instruments.attocube.anc300.**ANC300Controller**(*host*, *axisnames*, *passwd*, *query_delay=0.05*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Attocube ANC300 Piezo stage controller with several axes

**Parameters**

- **host** – host address of the instrument
- **axisnames** – a list of axis names which will be used to create properties with these names
- **passwd** – password for the attocube standard console
- **query_delay** – delay between sending and reading (default 0.05 sec)
- **kwargs** – Any valid key-word argument for TelnetAdapter

**property controllerBoardVersion**
Serial number of the controller board

**ground_all**()
Grounds all axis of the controller.

**stop_all**()
Stop all movements of the axis.

**property version**
Version number and instrument identification

**class** pymeasure.instruments.attocube.anc300.**Axis**(*controller*, *axis*)

Bases: object

Represents a single open loop axis of the Attocube ANC350

**Parameters**

- **axis** – axis identifier, integer from 1 to 7
- **controller** – ANC300Controller instance used for the communication

**property capacity**
Saved capacity value in nF of the axis.

**property frequency**
Frequency of the stepping motion in Hertz from 1 to 10000 Hz. This property can be set.

**measure_capacity**()
Obtains a new measurement of the capacity. The mode of the axis returns to 'gnd' after the measurement.

**Returns capacity** the freshly measured capacity in nF.

**property mode**
Axis mode. This can be 'gnd', 'inp', 'cap', 'stp', 'off', 'stp+', 'stp-'. Available modes depend on the actual axis model

**move**(*steps*, *gnd=True*)
Move 'steps' steps in the direction given by the sign of the argument. This method will change the mode of the axis automatically and ground the axis on the end if 'gnd' is True. The method returns only when the movement is finished.

**Parameters**

- **steps** – finite integer value of steps to be performed. A positive sign corresponds to upwards steps, a negative sign to downwards steps.
- **gnd** – bool, flag to decide if the axis should be grounded after completion of the movement

**property offset_voltage**
Offset voltage in Volts from 0 to 150 V. This property can be set.

**property output_voltage**
Output voltage in volts.

**property pattern_down**
step down pattern of the piezo drive. 256 values ranging from 0 to 255 representing the the sequence of output voltages within one step of the piezo drive. This property can be set, the set value needs to be an array with 256 integer values.

**property pattern_up**
step up pattern of the piezo drive. 256 values ranging from 0 to 255 representing the the sequence of output voltages within one step of the piezo drive. This property can be set, the set value needs to be an array with 256 integer values.

**property serial_nr**
Serial number of the axis

**property stepd**
Step downwards for N steps. Mode must be 'stp' and N must be positive.

**property stepu**
Step upwards for N steps. Mode must be 'stp' and N must be positive.

**stop**()
Stop any motion of the axis

**property voltage**
Amplitude of the stepping voltage in volts from 0 to 150 V. This property can be set.

## 7.14 BK Precision

This section contains specific documentation on the BK Precision instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.14.1 BK Precision 9130B DC Power Supply

**class** pymeasure.instruments.bkprecision.**BKPrecision9130B**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the BK Precision 9130B DC Power Supply interface for interacting with the instrument.

**property channel**
An integer property used to control which channel is selected. Can only take values [1, 2, 3].

**check_errors**()
Read all errors from the instrument.

**Returns** list of error entries

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property current**
Floating point property used to control current of the selected channel.

**property id**
Requests and returns the identification of the instrument.

**property options**
Requests and returns the device options installed.

**reset**()
Resets the instrument.

**shutdown**()
Brings the instrument to a safe and stable state

**property source_enabled**
A boolean property that controls whether the source is enabled, takes values True or False.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**property voltage**
Floating point property used to control voltage of the selected channel.

## 7.15 Danfysik

This section contains specific documentation on the Danfysik instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.15.1 Danfysik Serial Adapter

**class** pymeasure.instruments.danfysik.**DanfysikAdapter**(*port*)

Bases: *pymeasure.adapters.serial.SerialAdapter*

Provides a `SerialAdapter` with the specific baudrate and timeout for Danfysik serial communication.

Initiates the adapter to open serial communcation over the supplied port.

**Parameters** **port** – A string representing the serial port

**read**()

Overwrites the *SerialAdapter.read* method to automatically raise exceptions if errors are reported by the instrument.

**Returns** String ASCII response of the instrument

**Raises** An `Exception` if the Danfysik raises an error

**write**(*command*)

Overwrites the *SerialAdapter.write* method to automatically append a Unix-style linebreak at the end of the command.

**Parameters** **command** – SCPI command string to be sent to the instrument

### 7.15.2 Danfysik 8500 Power Supply

**class** pymeasure.instruments.danfysik.**Danfysik8500**(*port*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Danfysik 8500 Electromanget Current Supply and provides a high-level interface for interacting with the instrument

To allow user access to the Prolific Technology PL2303 Serial port adapter in Linux, create the file: `/etc/udev/rules.d/50-danfysik.rules`, with contents:

```
SUBSYSTEMS=="usb",ATTRS{idVendor}=="067b",ATTRS{idProduct}=="2303",MODE="0666",
↪SYMLINK+="danfysik"
```

Then reload the udev rules with:

```
sudo udevadm control --reload-rules
sudo udevadm trigger
```

The device will be accessible through the port `/dev/danfysik`.

**add_ramp_step**(*current*)

Adds a current step to the ramp set.

**Parameters** **current** – A current in Amps

**clear_ramp_set**()

Clears the ramp set.

**clear_sequence**(*stack*)

Clears the sequence by the stack number.

**Parameters** **stack** – A stack number between 0-15

**property current**

The actual current in Amps. This property can be set through *current_ppm*.

**property current_ppm**
The current in parts per million. This property can be set.

**property current_setpoint**
The setpoint for the current, which can deviate from the actual current (*current*) while the supply is in the process of setting the value.

**disable()**
Disables the flow of current.

**enable()**
Enables the flow of current.

**property id**
Reads the idenfitication information.

**is_current_stable()**
Returns True if the current is within 0.02 A of the setpoint value.

**is_enabled()**
Returns True if the current supply is enabled.

**is_ready()**
Returns True if the instrument is in the ready state.

**is_sequence_running**(*stack*)
Returns True if a sequence is running with a given stack number

**Parameters** **stack** – A stack number between 0-15

**local()**
Sets the instrument in local mode, where the front panel can be used.

**property polarity**
The polarity of the current supply, being either -1 or 1. This property can be set by suppling one of these values.

**ramp_to_current**(*current*, *points*, *delay_time=1*)
Executes *set_ramp_to_current()* and starts the ramp.

**remote()**
Sets the instrument in remote mode, where the the front panel is disabled.

**reset_interlocks()**
Resets the instrument interlocks.

**set_ramp_delay**(*time*)
Sets the ramp delay time in seconds.

**Parameters** **time** – The time delay time in seconds

**set_ramp_to_current**(*current*, *points*, *delay_time=1*)
Sets up a linear ramp from the initial current to a different current, with a number of points, and delay time.

**Parameters**

- **current** – The final current in Amps
- **points** – The number of linear points to traverse
- **delay_time** – A delay time in seconds

**set_sequence**(*stack*, *currents*, *times*, *multiplier=999999*)
Sets up an arbitrary ramp profile with a list of currents (Amps) and a list of interval times (seconds) on the specified stack number (0-15)

**property slew_rate**
The slew rate of the current sweep.

**start_ramp()**
Starts the current ramp.

**start_sequence(*stack*)**
Starts a sequence by the stack number.

**Parameters** **stack** – A stack number between 0-15

**property status**
A list of human-readable strings that contain the instrument status information, based on *status_hex*.

**property status_hex**
The status in hexadecimal. This value is parsed in *status* into a human-readable list.

**stop_ramp()**
Stops the current ramp.

**stop_sequence()**
Stops the currently running sequence.

**sync_sequence(*stack*, *delay=0*)**
Arms the ramp sequence to be triggered by a hardware input to pin P33 1&2 (10 to 24 V) or a TS command. If a delay is provided, the sequence will start after the delay.

**Parameters**

- **stack** – A stack number between 0-15
- **delay** – A delay time in seconds

**wait_for_current(*has_aborted=<function Danfysik8500.<lambda>>*, *delay=0.01*)**
Blocks the process until the current has stabilized. A provided function `has_aborted` can be supplied, which is checked after each delay time (in seconds) in addition to the stability check. This allows an abort feature to be integrated.

**Parameters**

- **has_aborted** – A function that returns True if the process should stop waiting
- **delay** – The delay time in seconds between each check for stability

**wait_for_ready(*has_aborted=<function Danfysik8500.<lambda>>*, *delay=0.01*)**
Blocks the process until the instrument is ready. A provided function `has_aborted` can be supplied, which is checked after each delay time (in seconds) in addition to the readiness check. This allows an abort feature to be integrated.

**Parameters**

- **has_aborted** – A function that returns True if the process should stop waiting
- **delay** – The delay time in seconds between each check for readiness

## 7.16 Delta Elektronika

This section contains specific documentation on the Delta Elektronika instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.16.1 Delta Elektronica SM7045D Power source

**class** pymeasure.instruments.deltaelektronika.**SM7045D**(*resourceName*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

This is the class for the SM 70-45 D power supply.

```
source = SM7045D("GPIB::8")

source.ramp_to_zero(1)               # Set output to 0 before enabling
source.enable()                      # Enables the output
source.current = 1                   # Sets a current of 1 Amps
```

**property current**

A floating point property that represents the output current of the power supply in Amps. This property can be set.

**disable**()

Enables remote shutdown, hence input will be disabled.

**enable**()

Disable remote shutdown, hence output will be enabled.

**property max_current**

A floating point property that represents the maximum output current of the power supply in Amps. This property can be set.

**property max_voltage**

A floating point property that represents the maximum output voltage of the power supply in Volts. This property can be set.

**property measure_current**

Measures the actual output current of the power supply in Amps.

**property measure_voltage**

Measures the actual output voltage of the power supply in Volts.

**ramp_to_current**(*target_current*, *current_step=0.1*)

Gradually increase/decrease current to target current.

**Parameters**

- **target_current** – Float that sets the target current (in A)
- **current_step** – Optional float that sets the current steps / ramp rate (in A/s)

**ramp_to_zero**(*current_step=0.1*)

Gradually decrease the current to zero.

**Parameters** **current_step** – Optional float that sets the current steps / ramp rate (in A/s)

**property rsd**

Check whether remote shutdown is enabled/disabled and thus if the output of the power supply is disabled/enabled.

**shutdown**()
Set the current to 0 A and disable the output of the power source.

**property voltage**
A floating point property that represents the output voltage setting of the power supply in Volts. This property can be set.

## 7.17 Edwards

This section contains specific documentation on the Edwards instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.17.1 Edwards nxds vacuum pump

pymeasure.instruments.edwards.**nxds**
alias of <module 'pymeasure.instruments.edwards.nxds' from '/home/docs/checkouts/readthedocs.org/user_builds/pymeasure/chec

## 7.18 Fluke

This section contains specific documentation on the Fluke instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.18.1 Fluke 7341 Temperature bath

**class** pymeasure.instruments.fluke.**Fluke7341**(*resource_name*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the compact constant temperature bath from Fluke

**property id**
Read the instrument model

**property set_point**
A *float* property to set the bath temperature set-point. Valid values are in the range -40 to 150 °C. The unit is as defined in property `unit`. This property can be read

**property temperature**
Read the current bath temperature. The unit is as defined in property `unit`.

**property unit**
A string property that controls the temperature unit. Possible values are *c* for Celsius and *f* for Fahrenheit`.

## 7.19 F.W. Bell

This section contains specific documentation on the F.W. Bell instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.19.1 F.W. Bell 5080 Handheld Gaussmeter

**class** pymeasure.instruments.fwbell.**FWBell5080**(*port*)

Bases: `pymeasure.instruments.instrument.Instrument`

Represents the F.W. Bell 5080 Handheld Gaussmeter and provides a high-level interface for interacting with the instrument

**Parameters port** – The serial port of the instrument

```
meter = FWBell5080('/dev/ttyUSB0')  # Connects over serial port /dev/ttyUSB0 (Linux)

meter.units = 'gauss'               # Sets the measurement units to Gauss
meter.range = 3e3                   # Sets the range to 3 kG
print(meter.field)                  # Reads and prints a field measurement in G

fields = meter.fields(100)          # Samples 100 field measurements
print(fields.mean(), fields.std())  # Prints the mean and standard deviation of the␣
↪samples
```

**ask**(*command*)

Overwrites the `Instrument.ask` method to remove the last 2 characters from the output.

**auto_range**()

Enables the auto range functionality.

**property field**

Reads a floating point value of the field in the appropriate units.

**fields**(*samples=1*)

Returns a numpy array of field samples for a given sample number.

**Parameters samples** – The number of samples to preform

**property id**

Reads the idenfitication information.

**property range**

A floating point property that controls the maximum field range in the active units. This can take the values of 300 G, 3 kG, and 30 kG for Gauss, 30 mT, 300 mT, and 3 T for Tesla, and 23.88 kAm, 238.8 kAm, and 2388 kAm for Amp-meter.

**read**()

Overwrites the `Instrument.read` method to remove the last 2 characters from the output.

**reset**()

Resets the instrument.

**property units**

A string property that controls the field units, which can take the values: 'gauss', 'gauss ac', 'tesla', 'tesla ac', 'amp-meter', and 'amp-meter ac'. The AC versions configure the instrument to measure AC.

**values**(*command*)

Overwrites the `Instrument.values` method to remove the lastv2 characters from the output.

## 7.20 Heidenhain

This section contains specific documentation on the Heidenhain instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.20.1 Heidenhain ND287 Position Display Unit

`pymeasure.instruments.heidenhain.`**`nd287`**

alias of <module 'pymeasure.instruments.heidenhain.nd287' from '/home/docs/checkouts/readthedocs.org/user_builds/pymeasure/

## 7.21 Hewlett Packard

This section contains specific documentation on the Hewlett Packard instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.21.1 HP 33120A Arbitrary Waveform Generator

**class** `pymeasure.instruments.hp.`**`HP33120A`**(*resourceName*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Hewlett Packard 33120A Arbitrary Waveform Generator and provides a high-level interface for interacting with the instrument.

**property amplitude**

A floating point property that controls the voltage amplitude of the output signal. The default units are in peak-to-peak Volts, but can be controlled by `amplitude_units`. The allowed range depends on the waveform shape and can be queried with `max_amplitude` and `min_amplitude`.

**property amplitude_units**

A string property that controls the units of the amplitude, which can take the values Vpp, Vrms, dBm, and default.

**beep**()

Causes a system beep.

**property frequency**

A floating point property that controls the frequency of the output in Hz. The allowed range depends on the waveform shape and can be queried with `max_frequency` and `min_frequency`.

**property max_amplitude**

Reads the maximum `amplitude` in Volts for the given shape

**property max_frequency**

Reads the maximum `frequency` in Hz for the given shape

**property max_offset**

Reads the maximum `offset` in Volts for the given shape

**property min_amplitude**

Reads the minimum `amplitude` in Volts for the given shape

**property min_frequency**

Reads the minimum `frequency` in Hz for the given shape

**property min_offset**
Reads the minimum `offset` in Volts for the given shape

**property offset**
A floating point property that controls the amplitude voltage offset in Volts. The allowed range depends on the waveform shape and can be queried with `max_offset` and `min_offset`.

**property shape**
A string property that controls the shape of the wave, which can take the values: sinusoid, square, triangle, ramp, noise, dc, and user.

### 7.21.2 HP 34401A Multimeter

**class** pymeasure.instruments.hp.**HP34401A**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the HP 34401A instrument.

**property current_ac**
AC current, in Amps

**property current_dc**
DC current, in Amps

**property resistance**
Resistance, in Ohms

**property resistance_4w**
Four-wires (remote sensing) resistance, in Ohms

**property voltage_ac**
AC voltage, in Volts

**property voltage_dc**
DC voltage, in Volts

### 7.21.3 HP 3478A Multimeter

**class** pymeasure.instruments.hp.**HP3478A**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Hewlett Packard 3748A 5 1/2 digit multimeter and provides a high-level interface for interacting with the instrument.

**class ERRORS**(*value*)
Bases: `enum.IntFlag`

Enum element for errror bit decoding

**GPIB_trigger()**
Initate trigger via low-level GPIB-command (aka GET - group execute trigger)

**class SRQ**(*value*)
Bases: `enum.IntFlag`

Enum element for SRQ mask bit decoding

**property SRQ_mask**
Return current SRQ mask, this property can be set,

bit assigment for SRQ:

| Bit (dec) | Description |
|---|---|
| 1 | SRQ when Data ready |
| 4 | SRQ when Syntax error |
| 8 | SRQ when internal error |
| 16 | front panel SQR button |
| 32 | SRQ by invalid calibration |

**property active_connectors**
Return selected connectors ("front"/"back"), based on front-panel selector switch

**property auto_range_enabled**
Property describing the auto-ranging status

| Value | Status |
|---|---|
| True | auto-range function activated |
| False | manual range selection / auto-range disabled |

The range can be set with the *range* property

**property auto_zero_enabled**
Return auto-zero status, this property can be set

| Value | Status |
|---|---|
| True | auto-zero active |
| False | auto-zero disabled |

**property calibration_enabled**
Return calibration enable switch setting, based on front-panel selector switch

| Value | Status |
|---|---|
| True | calbration possible |
| False | calibration locked |

**check_errors()**
Method to read the error status register

**Return error_status** one byte with the error status register content

**Rtype error_status** int

**classmethod decode_mode**(*function*)
Method to decode current mode

**Parameters** **function** – int indicating the measurement function selected

**Return cur_mode** string with the current measurement mode

**Rtype cur_mode** str

**classmethod decode_range**(*range_undecoded*, *function*)
Method to decode current range

**Parameters**

- **range_undecoded** – int to be decoded

- `function` – int indicating the measurement function selected

**Return cur_range** float value repesenting the active measurment range

**Rtype cur_range** float

`classmethod decode_status`(*status_bytes*, *field=None*)
Method to handle the decoding of the status bytes into something meaningfull

**Parameters**

- `status_bytes` – list of bytes to be decoded
- `field` – name of field to be returned

**Return ret_val** int status value

`static decode_trigger`(*status_bytes*)
Method to decode trigger mode

**Parameters** `status_bytes` – list of bytes to be decoded

**Return trigger_mode** string with the current trigger mode

**Rtype trigger_mode** str

`display_reset()`
Reset the display of the instrument.

`property display_text`
Displays up to 12 upper-case ASCII characters on the display.

`property display_text_no_symbol`
Displays up to 12 upper-case ASCII characters on the display and disables all symbols on the display.

`property error_status`
Checks the error status register

`get_status()`
Method to read the status bytes from the instrument :return current_status: a byte array representing the instrument status :rtype current_status: bytes

`property measure_ACI`
Returns the measured value for AC current as a float in A.

`property measure_ACV`
Returns the measured value for AC Voltage as a float in V.

`property measure_DCI`
Returns the measured value for DC current as a float in A.

`property measure_DCV`
Returns the measured value for DC Voltage as a float in V.

`property measure_R2W`
Returns the measured value for 2-wire resistance as a float in Ohm.

`property measure_R4W`
Returns the measured value for 4-wire resistance as a float in Ohm.

`property measure_Rext`
Returns the measured value for extended resistance mode (>30M, 2-wire) resistance as a float in Ohm.

`property mode`
Return current selected measurement mode, this propery can be set. Allowed values are

| Mode | Function |
|---|---|
| ACI | AC current |
| ACV | AC voltage |
| DCI | DC current |
| DCV | DC voltage |
| R2W | 2-wire resistance |
| R4W | 4-wire resistance |
| Rext | extended resistance method (requires additional 10 M resistor) |

**property range**
Returns the current measurement range, this property can be set.

Valid values are :

| Mode | Range |
|---|---|
| ACI | 0.3, 3, auto |
| ACV | 0.3, 3, 30, 300, auto |
| DCI | 0.3, 3, auto |
| DCV | 0.03, 0.3, 3, 30, 300, auto |
| R2W | 30, 300, 3000, 3E4, 3E5, 3E6, 3E7, auto |
| R4W | 30, 300, 3000, 3E4, 3E5, 3E6, 3E7, auto |
| Rext | 3E7, auto |

**reset()**
Initatiates a reset (like a power-on reset) of the HP3478A

**property resolution**
Returns current selected resolution, this property can be set.

Possible values are 3,4 or 5 (for 3 1/2, 4 1/2 or 5 1/2 digits of resolution)

**shutdown()**
provides a way to gracefully close the connection to the HP3478A

**property status**
Returns an object representing the current status of the unit.

**property trigger**
Return current selected trigger mode, this property can be set

Possibe values are:

| Value | Meaning |
|---|---|
| auto | automatic trigger (internal) |
| internal | automatic trigger (internal) |
| external | external trigger (connector on back or GET) |
| hold | holds the measurement |
| fast | fast trigger for AC measurements |

### 7.21.4 HP 8116A 50 MHz Pulse/Function Generator

**class** pymeasure.instruments.hp.**HP8116A**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Hewlett-Packard 8116A 50 MHz Pulse/Function Generator and provides a high-level interface for interacting with the instrument. The resolution for all floating point instrument parameters is 3 digits.

**class Digit**(*value*)

Bases: `enum.Enum`

Enum of the digits used with the autovernier (see *HP8116A.start_autovernier()*).

**class Direction**(*value*)

Bases: `enum.Enum`

Enum of the directions used with the autovernier (see *HP8116A.start_autovernier()*).

**GPIB_trigger**()

Initate trigger via low-level GPIB-command (aka GET - group execute trigger).

**property amplitude**

A floating point value that controls the amplitude of the output in V. The allowed amplitude range generally is 10 mV to 16 V, but it is also limited by the current offset.

**ask**(*command*, *num_bytes=None*)

Write a command to the instrument, read the response, and return the response as ASCII text.

**Parameters**

- **command** – The command to send to the instrument.
- **num_bytes** – The number of bytes to read from the instrument. If not specified, the number of bytes is automatically determined by the command.

**property autovernier_enabled**

A boolean property that controls whether the autovernier is enabled.

**property burst_number**

An integer value that controls the number of periods generated in a burst. The allowed range is 1 to 1999. It is only valid for units with Option 001 in one of the burst modes.

**check_errors**()

Check for errors in the 8116A.

**Returns** list of error entries or empty list if no error occurred.

**property complement_enabled**

A boolean property that controls whether the complement of the signal is generated.

**property complete**

This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property control_mode**

A string property that controls the control mode of the instrument. Possible values are 'off', 'FM', 'AM', 'PWM', 'VCO'.

**property duty_cycle**

An integer value that controls the duty cycle of the output in percent. The allowed range generally is 10 % to 90 %, but it also depends on the current frequency. It is valid for all shapes except 'pulse', where *pulse_width* is used instead.

**property frequency**
A floating point value that controls the frequency of the output in Hz. The allowed frequency range is 1 mHz to 52.5 MHz.

**property haversine_enabled**
A boolean property that controls whether a haversine/havertriangle signal is generated when in 'triggered', 'internal_burst' or 'external_burst' operating mode.

**property high_level**
A floating point value that controls the high level of the output in V. The allowed high level range generally is -7.9 V to 8 V, but it must be at least 10 mV greater than the low level.

**property limit_enabled**
A boolean property that controls whether parameter limiting is enabled.

**property low_level**
A floating point value that controls the low level of the output in V. The allowed low level range generally is -8 V to 7.9 V, but it must be at least 10 mV less than the high level.

**property offset**
A floating point value that controls the offset of the output in V. The allowed offset range generally is -7.95 V to 7.95 V, but it is also limited by the amplitude.

**property operating_mode**
A string property that controls the operating mode of the instrument. Possible values (without Option 001) are: 'normal', 'triggered', 'gate', 'external_width'. With Option 001, 'internal_sweep', 'external_sweep', 'external_width', 'external_pulse' are also available.

**property options**
Return the device options installed. The only possible option is 001.

**property output_enabled**
A boolean property that controls whether the output is enabled.

**property pulse_width**
A floating point value that controls the pulse width. The allowed pulse width range is 8 ns to 999 ms. The pulse width may not be larger than the period.

**read()**
Some units of the 8116A don't use the EOI line (see service note 8116A-07A). Therefore reads with automatic end-of-transmission detection will timeout. Instead, `adapter.read_bytes()` has to be used.

**property repetition_rate**
A floating point value that controls the repetition rate (= the time between bursts) in 'internal_burst' mode. The allowed range is 20 ns to 999 ms.

**reset()**
Initatiate a reset (like a power-on reset) of the 8116A.

**property shape**
A string property that controls the shape of the output waveform. Possible values are: 'dc', 'sine', 'triangle', 'square', 'pulse'.

**shutdown()**
Gracefully close the connection to the 8116A.

**start_autovernier**(*control*, *digit*, *direction*, *start_value=None*)
Start the autovernier on the specified control.

**Parameters**

- **control** – The control to change, pass as HP8116A.some_control. Allowed controls are frequency, amplitude, offset, duty_cycle, and pulse_width
- **digit** – The digit to change, type: *HP8116A.Digit*.
- **direction** – The direction in which to change the control, type: *HP8116A.Direction*.
- **start_value** – An optional value to start the autovernier at. If not specified, the current value of the control is used.

**property status**
Returns the status byte of the 8116A as an IntFlag-type enum.

**property sweep_marker_frequency**
A floating point value that controls the frequency marker in both sweep modes. At this frequency, the marker output switches from low to high. The allowed range is 1 mHz to 52.5 MHz.

**property sweep_start**
A floating point value that controls the start frequency in both sweep modes. The allowed range is 1 mHz to 52.5 MHz.

**property sweep_stop**
A floating point value that controls the stop frequency in both sweep modes. The allowed range is 1 mHz to 52.5 MHz.

**property sweep_time**
A floating point value that controls the sweep time per decade in both sweep modes. The sweep time is selectable in a 1-2-5 sequence between 10 ms and 500 s.

**property trigger_slope**
A string property that controls the slope the trigger triggers on. Possible values are: 'off', 'positive', 'negative'.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

**write**(*command*)
Write a command to the instrument and wait until the 8116A has interpreted it.

## 7.22 Keithley

This section contains specific documentation on the Keithley instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.22.1 Keithley 2000 Multimeter

**class** pymeasure.instruments.keithley.**Keithley2000**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithley 2000 Multimeter and provides a high-level interface for interacting with the instrument.

```
meter = Keithley2000("GPIB::1")
meter.measure_voltage()
print(meter.voltage)
```

**acquire_reference**(*mode=None*)
Sets the active value as the reference for the active mode, or can set another mode by its name.

**Parameters** **mode** – A valid *mode* name, or None for the active mode

**auto_range**(*mode=None*)
Sets the active mode to use auto-range, or can set another mode by its name.

**Parameters** **mode** – A valid *mode* name, or None for the active mode

**beep**(*frequency*, *duration*)
Sounds a system beep.

**Parameters**

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**property beep_state**
A string property that enables or disables the system status beeper, which can take the values: :code:'enabled' and :code:'disabled'.

**property buffer_data**
Returns a numpy array of values from the buffer.

**property buffer_points**
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**check_errors**()
Read all errors from the instrument.

**Returns** list of error entries

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**config_buffer**(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

**property current**
Reads a DC or AC current measurement in Amps, based on the active *mode*.

**property current_ac_bandwidth**
A floating point property that sets the AC current detector bandwidth in Hz, which can take the values 3, 30, and 300 Hz.

**property current_ac_digits**
An integer property that controls the number of digits in the AC current readings, which can take values from 4 to 7.

**property current_ac_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the AC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property current_ac_range**
A floating point property that controls the AC current range in Amps, which can take values from 0 to 3.1 A. Auto-range is disabled when this property is set.

**property current_ac_reference**
A floating point property that controls the AC current reference value in Amps, which can take values from -3.1 to 3.1 A.

**property current_digits**
An integer property that controls the number of digits in the DC current readings, which can take values from 4 to 7.

**property current_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property current_range**
A floating point property that controls the DC current range in Amps, which can take values from 0 to 3.1 A. Auto-range is disabled when this property is set.

**property current_reference**
A floating point property that controls the DC current reference value in Amps, which can take values from -3.1 to 3.1 A.

**disable_buffer()**
Disables the connection between measurements and the buffer, but does not abort the measurement process.

**disable_filter**(*mode=None*)
Disables the averaging filter for the active mode, or can set another mode by its name.

**Parameters** **mode** – A valid `mode` name, or None for the active mode

**disable_reference**(*mode=None*)
Disables the reference for the active mode, or can set another mode by its name.

**Parameters** **mode** – A valid `mode` name, or None for the active mode

**enable_filter**(*mode=None*, *type='repeat'*, *count=1*)
Enables the averaging filter for the active mode, or can set another mode by its name.

**Parameters**

- **mode** – A valid `mode` name, or None for the active mode
- **type** – The type of averaging filter, either 'repeat' or 'moving'.
- **count** – A number of averages, which can take take values from 1 to 100

**enable_reference**(*mode=None*)
Enables the reference for the active mode, or can set another mode by its name.

**Parameters** **mode** – A valid `mode` name, or None for the active mode

**property frequency**
Reads a frequency measurement in Hz, based on the active `mode`.

**property frequency_aperature**
A floating point property that controls the frequency aperature in seconds, which sets the integration period and measurement speed. Takes values from 0.01 to 1.0 s.

**property frequency_digits**
An integer property that controls the number of digits in the frequency readings, which can take values from 4 to 7.

**property frequency_reference**
A floating point property that controls the frequency reference value in Hz, which can take values from 0 to 15 MHz.

**property frequency_threshold**
A floating point property that controls the voltage signal threshold level in Volts for the frequency measurement, which can take values from 0 to 1010 V.

**property id**
Requests and returns the identification of the instrument.

**is_buffer_full()**
Returns True if the buffer is full of measurements.

**local()**
Returns control to the instrument panel, and enables the panel if disabled.

**measure_continuity()**
Configures the instrument to perform continuity testing.

**measure_current**(*max_current=0.01*, *ac=False*)
Configures the instrument to measure current, based on a maximum current to set the range, and a boolean flag to determine if DC or AC is required.

**Parameters**

- **max_current** – A current in Volts to set the current range
- **ac** – False for DC current, and True for AC current

**measure_diode()**
Configures the instrument to perform diode testing.

**measure_frequency()**
Configures the instrument to measure the frequency.

**measure_period()**
Configures the instrument to measure the period.

**measure_resistance**(*max_resistance=10000000.0*, *wires=2*)
Configures the instrument to measure voltage, based on a maximum voltage to set the range, and a boolean flag to determine if DC or AC is required.

**Parameters**

- **max_voltage** – A voltage in Volts to set the voltage range
- **ac** – False for DC voltage, and True for AC voltage

**measure_temperature()**
Configures the instrument to measure the temperature.

**measure_voltage**(*max_voltage=1*, *ac=False*)
Configures the instrument to measure voltage, based on a maximum voltage to set the range, and a boolean flag to determine if DC or AC is required.

**Parameters**

- **max_voltage** – A voltage in Volts to set the voltage range
- **ac** – False for DC voltage, and True for AC voltage

**property mode**
A string property that controls the configuration mode for measurements, which can take the values:

:code:'current' (DC), :code:'current ac', :code:'voltage' (DC), :code:'voltage ac', :code:'resistance' (2-wire), :code:'resistance 4W' (4-wire), :code:'period', :code:'frequency', :code:'temperature', :code:'diode', and :code:'frequency'.

**property options**
Requests and returns the device options installed.

**property period**
Reads a period measurement in seconds, based on the active `mode`.

**property period_aperature**
A floating point property that controls the period aperature in seconds, which sets the integration period and measurement speed. Takes values from 0.01 to 1.0 s.

**property period_digits**
An integer property that controls the number of digits in the period readings, which can take values from 4 to 7.

**property period_reference**
A floating point property that controls the period reference value in seconds, which can take values from 0 to 1 s.

**property period_threshold**
A floating point property that controls the voltage signal threshold level in Volts for the period measurement, which can take values from 0 to 1010 V.

**remote()**
Places the instrument in the remote state, which is does not need to be explicity called in general.

**remote_lock()**
Disables and locks the front panel controls to prevent changes during remote operations. This is disabled by calling `local()`.

**reset()**
Resets the instrument state.

**reset_buffer()**
Resets the buffer.

**property resistance**
Reads a resistance measurement in Ohms for both 2-wire and 4-wire configurations, based on the active `mode`.

**property resistance_4W_digits**
An integer property that controls the number of digits in the 4-wire resistance readings, which can take values from 4 to 7.

**property resistance_4W_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the 4-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property resistance_4W_range**
A floating point property that controls the 4-wire resistance range in Ohms, which can take values from 0 to 120 MOhms. Auto-range is disabled when this property is set.

**property resistance_4W_reference**
A floating point property that controls the 4-wire resistance reference value in Ohms, which can take values from 0 to 120 MOhms.

**property resistance_digits**
An integer property that controls the number of digits in the 2-wire resistance readings, which can take values from 4 to 7.

**property resistance_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property resistance_range**
A floating point property that controls the 2-wire resistance range in Ohms, which can take values from 0 to 120 MOhms. Auto-range is disabled when this property is set.

**property resistance_reference**
A floating point property that controls the 2-wire resistance reference value in Ohms, which can take values from 0 to 120 MOhms.

**shutdown()**
Brings the instrument to a safe and stable state

**start_buffer()**
Starts the buffer.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**stop_buffer()**
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

**property temperature**
Reads a temperature measurement in Celsius, based on the active `mode`.

**property temperature_digits**
An integer property that controls the number of digits in the temperature readings, which can take values from 4 to 7.

**property temperature_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the temperature measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property temperature_reference**
A floating point property that controls the temperature reference value in Celsius, which can take values from -200 to 1372 C.

**property trigger_count**
An integer property that controls the trigger count, which can take values from 1 to 9,999.

**property trigger_delay**
A floating point property that controls the trigger delay in seconds, which can take values from 1 to 9,999,999.999 s.

**property voltage**
Reads a DC or AC voltage measurement in Volts, based on the active `mode`.

**property voltage_ac_bandwidth**
A floating point property that sets the AC voltage detector bandwidth in Hz, which can take the values 3, 30, and 300 Hz.

**property voltage_ac_digits**
An integer property that controls the number of digits in the AC voltage readings, which can take values from 4 to 7.

**property voltage_ac_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the AC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property voltage_ac_range**
A floating point property that controls the AC voltage range in Volts, which can take values from 0 to 757.5 V. Auto-range is disabled when this property is set.

**property voltage_ac_reference**
A floating point property that controls the AC voltage reference value in Volts, which can take values from -757.5 to 757.5 Volts.

**property voltage_digits**
An integer property that controls the number of digits in the DC voltage readings, which can take values from 4 to 7.

**property voltage_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property voltage_range**
A floating point property that controls the DC voltage range in Volts, which can take values from 0 to 1010 V. Auto-range is disabled when this property is set.

**property voltage_reference**
A floating point property that controls the DC voltage reference value in Volts, which can take values from -1010 to 1010 V.

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

### 7.22.2 Keithley 2260B DC Power Supply

**class** pymeasure.instruments.keithley.**Keithley2260B**(*adapter*, *read_termination='\n'*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Keithley 2260B Power Supply (minimal implementation) and provides a high-level interface for interacting with the instrument.

For a connection through tcpip, the device only accepts connections at port 2268, which cannot be configured otherwise. example connection string: 'TCPIP::xxx.xxx.xxx.xxx::2268::SOCKET' the read termination for this interface is

```
source = Keithley2260B("GPIB::1")
source.voltage = 1
print(source.voltage)
print(source.current)
print(source.power)
print(source.applied)
```

**property applied**
Simultaneous control of voltage (volts) and current (amps). Values need to be supplied as tuple of (voltage, current). Depending on whether the instrument is in constant current or constant voltage mode, the values achieved by the instrument will differ from the ones set.

**check_errors()**
Logs any system errors reported by the instrument.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property current**
Reads the current (in Ampere) the dc power supply is putting out.

**property current_limit**
A floating point property that controls the source current in amps. This is not checked against the allowed range. Depending on whether the instrument is in constant current or constant voltage mode, this might differ from the actual current achieved.

**property enabled**
A boolean property that controls whether the source is enabled, takes values True or False.

**property error**
Returns a tuple of an error code and message from a single error.

**property id**
Requests and returns the identification of the instrument.

**property options**
Requests and returns the device options installed.

**property power**
Reads the power (in Watt) the dc power supply is putting out.

**reset()**
Resets the instrument.

**shutdown()**
Disable output, call parent function

**property status**
Requests and returns the status byte and Master Summary Status bit.

**property voltage**
Reads the voltage (in Volt) the dc power supply is putting out.

**property voltage_setpoint**
A floating point property that controls the source voltage in volts. This is not checked against the allowed range. Depending on whether the instrument is in constant current or constant voltage mode, this might differ from the actual voltage achieved.

### 7.22.3 Keithley 2306 Dual Channel Battery/Charger Simulator

`class pymeasure.instruments.keithley.Keithley2306(resourceName, **kwargs)`
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Keithley 2306 Dual Channel Battery/Charger Simulator.

`property both_channels_enabled`
A boolean setting that controls whether both channel outputs are enabled, takes values of True or False.

`check_errors()`
Read all errors from the instrument.

**Returns** list of error entries

`property complete`
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

`property display_brightness`
A floating point property that controls the display brightness, takes values beteween 0.0 and 1.0. A blank display is 0.0, 1/4 brightness is for values less or equal to 0.25, otherwise 1/2 brightness for values less than or equal to 0.5, otherwise 3/4 brightness for values less than or equal to 0.75, otherwise full brightness.

`property display_channel`
An integer property that controls the display channel, takes values 1 or 2.

`property display_enabled`
A boolean property that controls whether the display is enabled, takes values True or False.

`property display_text_data`
A string property that control text to be displayed, takes strings up to 32 characters.

`property display_text_enabled`
A boolean property that controls whether display text is enabled, takes values True or False.

`property id`
Requests and returns the identification of the instrument.

`property options`
Requests and returns the device options installed.

`reset()`
Resets the instrument.

`shutdown()`
Brings the instrument to a safe and stable state

`property status`
Requests and returns the status byte and Master Summary Status bit.

### 7.22.4 Keithley 2400 SourceMeter

**class** pymeasure.instruments.keithley.**Keithley2400**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 2400 SourceMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2400("GPIB::1")

keithley.apply_current()                # Sets up to source current
keithley.source_current_range = 10e-3   # Sets the source current range to 10 mA
keithley.compliance_voltage = 10        # Sets the compliance voltage to 10 V
keithley.source_current = 0             # Sets the source current to 0 mA
keithley.enable_source()                # Enables the source output

keithley.measure_voltage()              # Sets up to measure voltage

keithley.ramp_to_current(5e-3)          # Ramps the current to 5 mA
print(keithley.voltage)                 # Prints the voltage in Volts

keithley.shutdown()                     # Ramps the current to 0 mA and disables output
```

**apply_current**(*current_range=None*, *compliance_voltage=0.1*)

Configures the instrument to apply a source current, and uses an auto range unless a current range is specified. The compliance voltage is also set.

**Parameters**

- **compliance_voltage** – A float in the correct range for a *compliance_voltage*
- **current_range** – A *current_range* value or None

**apply_voltage**(*voltage_range=None*, *compliance_current=0.1*)

Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified. The compliance current is also set.

**Parameters**

- **compliance_current** – A float in the correct range for a *compliance_current*
- **voltage_range** – A *voltage_range* value or None

**property auto_output_off**

A boolean property that enables or disables the auto output-off. Valid values are True (output off after measurement) and False (output stays on after measurement).

**auto_range_source**()

Configures the source to use an automatic range.

**property auto_zero**

A property that controls the auto zero option. Valid values are True (enabled) and False (disabled) and 'ONCE' (force immediate).

**beep**(*frequency*, *duration*)

Sounds a system beep.

**Parameters**

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz

- `duration` – A time in seconds between 0 and 7.9 seconds

**property buffer_data**
Returns a numpy array of values from the buffer.

**property buffer_points**
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**check_errors()**
Logs any system errors reported by the instrument.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property compliance_current**
A floating point property that controls the compliance current in Amps.

**property compliance_voltage**
A floating point property that controls the compliance voltage in Volts.

**config_buffer**(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- `points` – The number of points in the buffer.
- `delay` – The delay time in seconds.

**property current**
Reads the current in Amps, if configured for this reading.

**property current_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property current_range**
A floating point property that controls the measurement current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

**disable_buffer()**
Disables the connection between measurements and the buffer, but does not abort the measurement process.

**disable_output_trigger()**
Disables the output trigger for the Trigger layer

**disable_source()**
Disables the source of current or voltage depending on the configuration of the instrument.

**property display_enabled**
A boolean property that controls whether or not the display of the sourcemeter is enabled. Valid values are True and False.

**enable_source()**
Enables the source of current or voltage depending on the configuration of the instrument.

**property error**
Returns a tuple of an error code and message from a single error.

**property filter_count**
: A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

**property filter_state**
: A string property that controls if the filter is active.

**property filter_type**
: A String property that controls the filter's type. REP : Repeating filter MOV : Moving filter

**property id**
: Requests and returns the identification of the instrument.

**is_buffer_full()**
: Returns True if the buffer is full of measurements.

**property line_frequency**
: An integer property that controls the line frequency in Hertz. Valid values are 50 and 60.

**property line_frequency_auto**
: A boolean property that enables or disables auto line frequency. Valid values are True and False.

**property max_current**
: Returns the maximum current from the buffer

**property max_resistance**
: Returns the maximum resistance from the buffer

**property max_voltage**
: Returns the maximum voltage from the buffer

**property maximums**
: Returns the calculated maximums for voltage, current, and resistance from the buffer data as a list.

**property mean_current**
: Returns the mean current from the buffer

**property mean_resistance**
: Returns the mean resistance from the buffer

**property mean_voltage**
: Returns the mean voltage from the buffer

**property means**
: Reads the calculated means (averages) for voltage, current, and resistance from the buffer data as a list.

**property measure_concurent_functions**
: A boolean property that enables or disables the ability to measure more than one function simultaneously. When disabled, volts function is enabled. Valid values are True and False.

**measure_current**(*nplc=1*, *current=0.000105*, *auto_range=True*)
: Configures the measurement of current.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **current** – Upper limit of current in Amps, from -1.05 A to 1.05 A
- **auto_range** – Enables auto_range if True, else uses the set current

**measure_resistance**(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
: Configures the measurement of resistance.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **resistance** – Upper limit of resistance in Ohms, from -210 MOhms to 210 MOhms
- **auto_range** – Enables auto_range if True, else uses the set resistance

**measure_voltage**(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **voltage** – Upper limit of voltage in Volts, from -210 V to 210 V
- **auto_range** – Enables auto_range if True, else uses the set voltage

**property min_current**
Returns the minimum current from the buffer

**property min_resistance**
Returns the minimum resistance from the buffer

**property min_voltage**
Returns the minimum voltage from the buffer

**property minimums**
Returns the calculated minimums for voltage, current, and resistance from the buffer data as a list.

**property options**
Requests and returns the device options installed.

**property output_off_state**
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

**output_trigger_on_external**(*line=1*, *after='DEL'*)
Configures the output trigger on the specified trigger link line number, with the option of supplying the part of the measurement after which the trigger should be generated (default to delay, which is right before the measurement)

**Parameters**

- **line** – A trigger line from 1 to 4
- **after** – An event string that determines when to trigger

**ramp_to_current**(*target_current*, *steps=30*, *pause=0.02*)
Ramps to a target current from the set current value over a certain number of linear steps, each separated by a pause duration.

**Parameters**

- **target_current** – A current in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

**ramp_to_voltage**(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

**Parameters**

- **target_voltage** – A voltage in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

**reset**()
Resets the instrument and clears the queue.

**reset_buffer**()
Resets the buffer.

**property resistance**
Reads the resistance in Ohms, if configured for this reading.

**property resistance_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property resistance_range**
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 210 MOhms. Auto-range is disabled when this property is set.

**sample_continuously**()
Causes the instrument to continuously read samples and turns off any buffer or output triggering

**set_timed_arm**(*interval*)
Sets up the measurement to be taken with the internal trigger at a variable sampling rate defined by the interval in seconds between sampling points

**set_trigger_counts**(*arm*, *trigger*)
Sets the number of counts for both the sweeps (arm) and the points in those sweeps (trigger), where the total number of points can not exceed 2500

**shutdown**()
Ensures that the current or voltage is turned to zero and disables the output.

**property source_current**
A floating point property that controls the source current in Amps.

**property source_current_range**
A floating point property that controls the source current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

**property source_delay**
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

**property source_delay_auto**
A boolean property that enables or disables auto delay. Valid values are True and False.

**property source_enabled**
A boolean property that controls whether the source is enabled, takes values True or False. The convenience methods `enable_source()` and `disable_source()` can also be used.

**property source_mode**
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods `apply_current()` and `apply_voltage()` can also be used.

**property source_voltage**
A floating point property that controls the source voltage in Volts.

**property source_voltage_range**
A floating point property that controls the source voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

**property standard_devs**
Returns the calculated standard deviations for voltage, current, and resistance from the buffer data as a list.

**start_buffer()**
Starts the buffer.

**status()**
Requests and returns the status byte and Master Summary Status bit.

**property std_current**
Returns the current standard deviation from the buffer

**property std_resistance**
Returns the resistance standard deviation from the buffer

**property std_voltage**
Returns the voltage standard deviation from the buffer

**stop_buffer()**
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

**triad**(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

**Parameters**

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**trigger()**
Executes a bus trigger, which can be used when *trigger_on_bus()* is configured.

**property trigger_count**
An integer property that controls the trigger count, which can take values from 1 to 9,999.

**property trigger_delay**
A floating point property that controls the trigger delay in seconds, which can take values from 0 to 999.9999 s.

**trigger_immediately()**
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

**trigger_on_bus()**
Configures the trigger to detect events based on the bus trigger, which can be activated by *trigger()*.

**trigger_on_external**(*line=1*)
Configures the measurement trigger to be taken from a specific line of an external trigger

**Parameters** **line** – A trigger line from 1 to 4

**use_front_terminals()**
Enables the front terminals for measurement, and disables the rear terminals.

**use_rear_terminals()**
Enables the rear terminals for measurement, and disables the front terminals.

**property voltage**
Reads the voltage in Volts, if configured for this reading.

**property voltage_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property voltage_range**
A floating point property that controls the measurement voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

**property wires**
An integer property that controls the number of wires in use for resistance measurements, which can take the value of 2 or 4.

### 7.22.5 Keithley 2450 SourceMeter

**class** pymeasure.instruments.keithley.**Keithley2450**(*adapter*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`, `pymeasure.instruments.keithley.buffer.KeithleyBuffer`

Represents the Keithely 2450 SourceMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2450("GPIB::1")

keithley.apply_current()                # Sets up to source current
keithley.source_current_range = 10e-3   # Sets the source current range to 10 mA
keithley.compliance_voltage = 10        # Sets the compliance voltage to 10 V
keithley.source_current = 0             # Sets the source current to 0 mA
keithley.enable_source()                # Enables the source output

keithley.measure_voltage()              # Sets up to measure voltage

keithley.ramp_to_current(5e-3)          # Ramps the current to 5 mA
print(keithley.voltage)                 # Prints the voltage in Volts

keithley.shutdown()                     # Ramps the current to 0 mA and disables␣
↪output
```

**apply_current**(*current_range=None*, *compliance_voltage=0.1*)
Configures the instrument to apply a source current, and uses an auto range unless a current range is specified. The compliance voltage is also set.

**Parameters**

- **compliance_voltage** – A float in the correct range for a `compliance_voltage`

- **current_range** – A *current_range* value or None

**apply_voltage**(*voltage_range=None*, *compliance_current=0.1*)
Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified. The compliance current is also set.

**Parameters**

- **compliance_current** – A float in the correct range for a *compliance_current*
- **voltage_range** – A *voltage_range* value or None

**auto_range_source**()
Configures the source to use an automatic range.

**beep**(*frequency*, *duration*)
Sounds a system beep.

**Parameters**

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**property buffer_data**
Returns a numpy array of values from the buffer.

**property buffer_points**
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**check_errors**()
Logs any system errors reported by the instrument.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property compliance_current**
A floating point property that controls the compliance current in Amps.

**property compliance_voltage**
A floating point property that controls the compliance voltage in Volts.

**config_buffer**(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

**property current**
Reads the current in Amps, if configured for this reading.

**property current_filter_count**
A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

**property current_filter_state**
A string property that controls if the filter is active.

**property current_filter_type**
A String property that controls the filter's type for the current. REP : Repeating filter MOV : Moving filter

**property current_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property current_output_off_state**
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

**property current_range**
A floating point property that controls the measurement current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

**disable_buffer()**
Disables the connection between measurements and the buffer, but does not abort the measurement process.

**disable_source()**
Disables the source of current or voltage depending on the configuration of the instrument.

**enable_source()**
Enables the source of current or voltage depending on the configuration of the instrument.

**property error**
Returns a tuple of an error code and message from a single error.

**property id**
Requests and returns the identification of the instrument.

**is_buffer_full()**
Returns True if the buffer is full of measurements.

**property max_current**
Returns the maximum current from the buffer

**property max_resistance**
Returns the maximum resistance from the buffer

**property max_voltage**
Returns the maximum voltage from the buffer

**property maximums**
Returns the calculated maximums for voltage, current, and resistance from the buffer data as a list.

**property mean_current**
Returns the mean current from the buffer

**property mean_resistance**
Returns the mean resistance from the buffer

**property mean_voltage**
Returns the mean voltage from the buffer

**property means**
Reads the calculated means (averages) for voltage, current, and resistance from the buffer data as a list.

**measure_current**(*nplc=1*, *current=0.000105*, *auto_range=True*)
Configures the measurement of current.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **current** – Upper limit of current in Amps, from -1.05 A to 1.05 A
- **auto_range** – Enables auto_range if True, else uses the set current

**measure_resistance**(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
Configures the measurement of resistance.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **resistance** – Upper limit of resistance in Ohms, from -210 MOhms to 210 MOhms
- **auto_range** – Enables auto_range if True, else uses the set resistance

**measure_voltage**(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

**Parameters**

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **voltage** – Upper limit of voltage in Volts, from -210 V to 210 V
- **auto_range** – Enables auto_range if True, else uses the set voltage

**property min_current**
Returns the minimum current from the buffer

**property min_resistance**
Returns the minimum resistance from the buffer

**property min_voltage**
Returns the minimum voltage from the buffer

**property minimums**
Returns the calculated minimums for voltage, current, and resistance from the buffer data as a list.

**property options**
Requests and returns the device options installed.

**ramp_to_current**(*target_current*, *steps=30*, *pause=0.02*)
Ramps to a target current from the set current value over a certain number of linear steps, each separated by a pause duration.

**Parameters**

- **target_current** – A current in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

**ramp_to_voltage**(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

**Parameters**

- **target_voltage** – A voltage in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

**reset()**
Resets the instrument and clears the queue.

**reset_buffer()**
Resets the buffer.

**property resistance**
Reads the resistance in Ohms, if configured for this reading.

**property resistance_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property resistance_range**
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 210 MOhms. Auto-range is disabled when this property is set.

**shutdown()**
Ensures that the current or voltage is turned to zero and disables the output.

**property source_current**
A floating point property that controls the source current in Amps.

**property source_current_delay**
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

**property source_current_delay_auto**
A boolean property that enables or disables auto delay. Valid values are True and False.

**property source_current_range**
A floating point property that controls the source current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

**property source_enabled**
Reads a boolean value that is True if the source is enabled.

**property source_mode**
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods `apply_current()` and `apply_voltage()` can also be used.

**property source_voltage**
A floating point property that controls the source voltage in Volts.

**property source_voltage_delay**
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

**property source_voltage_delay_auto**
A boolean property that enables or disables auto delay. Valid values are True and False.

**property source_voltage_range**
A floating point property that controls the source voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

**property standard_devs**
Returns the calculated standard deviations for voltage, current, and resistance from the buffer data as a list.

`start_buffer()`
Starts the buffer.

`property status`
Requests and returns the status byte and Master Summary Status bit.

`property std_current`
Returns the current standard deviation from the buffer

`property std_resistance`
Returns the resistance standard deviation from the buffer

`property std_voltage`
Returns the voltage standard deviation from the buffer

`stop_buffer()`
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

`triad`(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

**Parameters**

- `base_frequency` – A frequency in Hz between 65 Hz and 1.3 MHz
- `duration` – A time in seconds between 0 and 7.9 seconds

`trigger()`
Executes a bus trigger.

`use_front_terminals()`
Enables the front terminals for measurement, and disables the rear terminals.

`use_rear_terminals()`
Enables the rear terminals for measurement, and disables the front terminals.

`property voltage`
Reads the voltage in Volts, if configured for this reading.

`property voltage_filter_count`
A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

`property voltage_filter_type`
A String property that controls the filter's type for the current. REP : Repeating filter MOV : Moving filter

`property voltage_nplc`
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

`property voltage_output_off_state`
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

`property voltage_range`
A floating point property that controls the measurement voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

**property wires**
An integer property that controls the number of wires in use for resistance measurements, which can take the value of 2 or 4.

### 7.22.6 Keithley 2700 MultiMeter/Switch System

**class** pymeasure.instruments.keithley.**Keithley2700**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 2700 Multimeter/Switch System and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2700("GPIB::1")
```

**beep**(*frequency*, *duration*)
Sounds a system beep.

**Parameters**

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**property buffer_data**
Returns a numpy array of values from the buffer.

**property buffer_points**
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**channels_from_rows_columns**(*rows*, *columns*, *slot=None*)
Determine the channel numbers between column(s) and row(s) of the 7709 connection matrix. Returns a list of channel numbers. Only one of the parameters 'rows' or 'columns' can be "all"

**Parameters**

- **rows** – row number or list of numbers; can also be "all"
- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

**check_errors**()
Logs any system errors reported by the instrument.

**close_rows_to_columns**(*rows*, *columns*, *slot=None*)
Closes (connects) the channels between column(s) and row(s) of the 7709 connection matrix. Only one of the parameters 'rows' or 'columns' can be "all"

**Parameters**

- **rows** – row number or list of numbers; can also be "all"
- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

**property closed_channels**
Parameter that controls the opened and closed channels. All mentioned channels are closed, other channels will be opened.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**config_buffer**(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

**determine_valid_channels**()
Determine what cards are installed into the Keithley 2700 and from that determine what channels are valid.

**disable_buffer**()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

**display_closed_channels**()
Show the presently closed channels on the display of the Keithley 2700.

**property display_text**
A string property that controls the text shown on the display of the Keithley 2700. Text can be up to 12 ASCII characters and must be enabled to show.

**property error**
Returns a tuple of an error code and message from a single error.

**get_state_of_channels**(*channels*)
Get the open or closed state of the specified channels

**Parameters** **channels** – a list of channel numbers, or single channel number

**property id**
Requests and returns the identification of the instrument.

**is_buffer_full**()
Returns True if the buffer is full of measurements.

**open_all_channels**()
Open all channels of the Keithley 2700.

**property open_channels**
A parameter that opens the specified list of channels. Can only be set.

**open_rows_to_columns**(*rows*, *columns*, *slot=None*)
Opens (disconnects) the channels between column(s) and row(s) of the 7709 connection matrix. Only one of the parameters 'rows' or 'columns' can be "all"

**Parameters**

- **rows** – row number or list of numbers; can also be "all"

- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

**property options**
Property that lists the installed cards in the Keithley 2700. Returns a dict with the integer card numbers on the position.

**reset()**
Resets the instrument and clears the queue.

**reset_buffer()**
Resets the buffer.

**shutdown()**
Brings the instrument to a safe and stable state

**start_buffer()**
Starts the buffer.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**stop_buffer()**
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

**property text_enabled**
A boolean property that controls whether a text message can be shown on the display of the Keithley 2700.

**triad**(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

**Parameters**

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

### 7.22.7 Keithley 6221 AC and DC Current Source

**class** pymeasure.instruments.keithley.**Keithley6221**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, `pymeasure.instruments.keithley.buffer.KeithleyBuffer`

Represents the Keithely 6221 AC and DC current source and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley6221("GPIB::1")
keithley.clear()

# Use the keithley as an AC source
keithley.waveform_function = "square"   # Set a square waveform
keithley.waveform_amplitude = 0.05      # Set the amplitude in Amps
keithley.waveform_offset = 0            # Set zero offset
keithley.source_compliance = 10         # Set compliance (limit) in V
keithley.waveform_dutycycle = 50        # Set duty cycle of wave in %
keithley.waveform_frequency = 347       # Set the frequency in Hz
keithley.waveform_ranging = "best"      # Set optimal output ranging
keithley.waveform_duration_cycles = 100 # Set duration of the waveform

# Link end of waveform to Service Request status bit
keithley.operation_event_enabled = 128  # OSB listens to end of wave
keithley.srq_event_enabled = 128        # SRQ listens to OSB

keithley.waveform_arm()                 # Arm (load) the waveform

keithley.waveform_start()               # Start the waveform

keithley.adapter.wait_for_srq()         # Wait for the pulse to finish

keithley.waveform_abort()               # Disarm (unload) the waveform

keithley.shutdown()                     # Disables output
```

**beep**(*frequency*, *duration*)
Sounds a system beep.

**Parameters**

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**property buffer_data**
Returns a numpy array of values from the buffer.

**property buffer_points**
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**check_errors**()
Logs any system errors reported by the instrument.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**config_buffer**(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

**define_arbitary_waveform**(*datapoints*, *location=1*)
Define the data points for the arbitrary waveform and copy the defined waveform into the given storage location.

**Parameters**

- **datapoints** – a list (or numpy array) of the data points; all values have to be between -1 and 1; 100 points maximum.
- **location** – integer storage location to store the waveform in. Value must be in range 1 to 4.

**disable_buffer**()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

**disable_output_trigger**()
Disables the output trigger for the Trigger layer

**disable_source**()
Disables the source of current or voltage depending on the configuration of the instrument.

**property display_enabled**
A boolean property that controls whether or not the display of the sourcemeter is enabled. Valid values are True and False.

**enable_source**()
Enables the source of current or voltage depending on the configuration of the instrument.

**property error**
Returns a tuple of an error code and message from a single error.

**property id**
Requests and returns the identification of the instrument.

**is_buffer_full**()
Returns True if the buffer is full of measurements.

**property measurement_event_enabled**
An integer value that controls which measurement events are registered in the Measurement Summary Bit (MSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

**property measurement_events**
An integer value that reads which measurement events have been registered in the Measurement event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

**property operation_event_enabled**
An integer value that controls which operation events are registered in the Operation Summary Bit (OSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

**property operation_events**
An integer value that reads which operation events have been registered in the Operation event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

**property options**
Requests and returns the device options installed.

**property output_low_grounded**
A boolean property that controls whether the low output of the triax connection is connected to earth ground (True) or is floating (False).

**output_trigger_on_external**(*line=1*, *after='DEL'*)
Configures the output trigger on the specified trigger link line number, with the option of supplying the part of the measurement after which the trigger should be generated (default to delay, which is right before the measurement)

**Parameters**

- **line** – A trigger line from 1 to 4
- **after** – An event string that determines when to trigger

**property questionable_event_enabled**
An integer value that controls which questionable events are registered in the Questionable Summary Bit (QSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

**property questionable_events**
An integer value that reads which questionable events have been registered in the Questionable event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

**reset**()
Resets the instrument and clears the queue.

**reset_buffer**()
Resets the buffer.

**set_timed_arm**(*interval*)
Sets up the measurement to be taken with the internal trigger at a variable sampling rate defined by the interval in seconds between sampling points

**shutdown**()
Disables the output.

**property source_auto_range**
A boolean property that controls the auto range of the current source. Valid values are True or False.

**property source_compliance**
A floating point property that controls the compliance of the current source in Volts. valid values are in range 0.1 [V] to 105 [V].

**property source_current**
A floating point property that controls the source current in Amps.

**property source_delay**
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 1e-3 [seconds] and 999999.999 [seconds].

**property source_enabled**
A boolean property that controls whether the source is enabled, takes values True or False. The convenience methods `enable_source()` and `disable_source()` can also be used.

**property source_range**
A floating point property that controls the source current range in Amps, which can take values between -0.105 A and +0.105 A. Auto-range is disabled when this property is set.

**property srq_event_enabled**
An integer value that controls which event registers trigger the Service Request (SRQ) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

**property standard_event_enabled**
An integer value that controls which standard events are registered in the Event Summary Bit (ESB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

**property standard_events**
An integer value that reads which standard events have been registered in the Standard event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

**start_buffer()**
Starts the buffer.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**stop_buffer()**
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

**triad**(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

**Parameters**

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

**trigger()**
Executes a bus trigger, which can be used when `trigger_on_bus()` is configured.

**trigger_immediately()**
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

**trigger_on_bus()**
Configures the trigger to detect events based on the bus trigger, which can be activated by `trigger()`.

**trigger_on_external**(*line=1*)
Configures the measurement trigger to be taken from a specific line of an external trigger

**Parameters** **line** – A trigger line from 1 to 4

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

**waveform_abort()**
Abort the waveform output and disarm the waveform function.

**property waveform_amplitude**
A floating point property that controls the (peak) amplitude of the waveform in Amps. Valid values are in range 2e-12 to 0.105.

**waveform_arm()**
Arm the current waveform function.

**property waveform_duration_cycles**
A floating point property that controls the duration of the waveform in cycles. Valid values are in range 1e-3 to 99999999900.

**waveform_duration_set_infinity()**
Set the waveform duration to infinity.

**property waveform_duration_time**
A floating point property that controls the duration of the waveform in seconds. Valid values are in range 100e-9 to 999999.999.

**property waveform_dutycycle**
A floating point property that controls the duty-cycle of the waveform in percent for the square and ramp waves. Valid values are in range 0 to 100.

**property waveform_frequency**
A floating point property that controls the frequency of the waveform in Hertz. Valid values are in range 1e-3 to 1e5.

**property waveform_function**
A string property that controls the selected wave function. Valid values are "sine", "ramp", "square", "arbitrary1", "arbitrary2", "arbitrary3" and "arbitrary4".

**property waveform_offset**
A floating point property that controls the offset of the waveform in Amps. Valid values are in range -0.105 to 0.105.

**property waveform_ranging**
A string property that controls the source ranging of the waveform. Valid values are "best" and "fixed".

**waveform_start()**
Start the waveform output. Must already be armed

**property waveform_use_phasemarker**
A boolean property that controls whether the phase marker option is turned on or of. Valid values True (on) or False (off). Other settings for the phase marker have not yet been implemented.

### 7.22.8 Keithley 6517B Electrometer

**class** pymeasure.instruments.keithley.**Keithley6517B**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 6517B ElectroMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley6517B("GPIB::1")

keithley.apply_voltage()              # Sets up to source current
keithley.source_voltage_range = 200   # Sets the source voltage
                                      # range to 200 V
```

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```
keithley.source_voltage = 20          # Sets the source voltage to 20 V
keithley.enable_source()              # Enables the source output

keithley.measure_resistance()         # Sets up to measure resistance

keithley.ramp_to_voltage(50)          # Ramps the voltage to 50 V
print(keithley.resistance)            # Prints the resistance in Ohms

keithley.shutdown()                   # Ramps the voltage to 0 V
                                      # and disables output
```

**apply_voltage**(*voltage_range=None*)

Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified.

**Parameters** **voltage_range** – A `voltage_range` value or None (activates auto range)

**auto_range_source**()

Configures the source to use an automatic range.

**property buffer_data**

Returns a numpy array of values from the buffer.

**property buffer_points**

An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

**check_errors**()

Logs any system errors reported by the instrument.

**property complete**

This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**config_buffer**(*points=64*, *delay=0*)

Configures the measurement buffer for a number of points, to be taken with a specified delay.

**Parameters**

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

**property current**

Reads the current in Amps, if configured for this reading.

**property current_nplc**

A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property current_range**

A floating point property that controls the measurement current range in Amps, which can take values between -20 and +20 mA. Auto-range is disabled when this property is set.

**disable_buffer**()

Disables the connection between measurements and the buffer, but does not abort the measurement process.

`disable_source()`
Disables the source of current or voltage depending on the configuration of the instrument.

`enable_source()`
Enables the source of current or voltage depending on the configuration of the instrument.

`property error`
Returns a tuple of an error code and message from a single error.

`property id`
Requests and returns the identification of the instrument.

`is_buffer_full()`
Returns True if the buffer is full of measurements.

`measure_current`(*nplc=1*, *current=0.000105*, *auto_range=True*)
Configures the measurement of current.

**Parameters**

- `nplc` – Number of power line cycles (NPLC) from 0.01 to 10
- `current` – Upper limit of current in Amps, from -21 mA to 21 mA
- `auto_range` – Enables auto_range if True, else uses the current_range attribut

`measure_resistance`(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
Configures the measurement of resistance.

**Parameters**

- `nplc` – Number of power line cycles (NPLC) from 0.01 to 10
- `resistance` – Upper limit of resistance in Ohms, from -210 POhms to 210 POhms
- `auto_range` – Enables auto_range if True, else uses the resistance_range attribut

`measure_voltage`(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

**Parameters**

- `nplc` – Number of power line cycles (NPLC) from 0.01 to 10
- `voltage` – Upper limit of voltage in Volts, from -1000 V to 1000 V
- `auto_range` – Enables auto_range if True, else uses the voltage_range attribut

`property options`
Requests and returns the device options installed.

`ramp_to_voltage`(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

**Parameters**

- `target_voltage` – A voltage in Volts
- `steps` – An integer number of steps
- `pause` – A pause duration in seconds to wait between steps

`reset()`
Resets the instrument and clears the queue.

**reset_buffer()**
Resets the buffer.

**property resistance**
Reads the resistance in Ohms, if configured for this reading.

**property resistance_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property resistance_range**
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 100e18 Ohms. Auto-range is disabled when this property is set.

**shutdown()**
Ensures that the current or voltage is turned to zero and disables the output.

**property source_current_resistance_limit**
Boolean property which enables or disables resistance current limit

**property source_enabled**
Reads a boolean value that is True if the source is enabled.

**property source_voltage**
A floating point property that controls the source voltage in Volts.

**property source_voltage_range**
A floating point property that controls the source voltage range in Volts, which can take values from -1000 to 1000 V. Auto-range is disabled when this property is set.

**start_buffer()**
Starts the buffer.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**stop_buffer()**
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

**trigger()**
Executes a bus trigger, which can be used when *trigger_on_bus()* is configured.

**trigger_immediately()**
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

**trigger_on_bus()**
Configures the trigger to detect events based on the bus trigger, which can be activated by *trigger()*.

**property voltage**
Reads the voltage in Volts, if configured for this reading.

**property voltage_nplc**
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

**property voltage_range**
A floating point property that controls the measurement voltage range in Volts, which can take values from -1000 to 1000 V. Auto-range is disabled when this property is set.

**wait_for_buffer**(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

**Parameters**

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

### 7.22.9 Keithley 2750 Multimeter/Switch System

**class** pymeasure.instruments.keithley.**Keithley2750**(*adapter*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Keithley2750 multimeter/switch system and provides a high-level interface for interacting with the instrument.

**check_errors**()
Read all errors from the instrument.

**Returns** list of error entries

**close**(*channel*)
Closes (connects) the specified channel.

**Parameters** **channel** (*int*) – 3-digit number for the channel

**Returns** None

**property closed_channels**
Reads the list of closed channels

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property id**
Requests and returns the identification of the instrument.

**open**(*channel*)
Opens (disconnects) the specified channel.

**Parameters** **channel** (*int*) – 3-digit number for the channel

**Returns** None

**open_all**()
Opens (disconnects) all the channels on the switch matrix.

**Returns** None

**property options**
Requests and returns the device options installed.

**reset**()
Resets the instrument.

**shutdown**()
Brings the instrument to a safe and stable state

**property status**
Requests and returns the status byte and Master Summary Status bit.

### 7.22.10 Keithley 2600 SourceMeter

**class** pymeasure.instruments.keithley.**Keithley2600**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keithley 2600 series (channel A and B) SourceMeter

**check_errors()**
Logs any system errors reported by the instrument.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property error**
Returns a tuple of an error code and message from a single error.

**property id**
Requests and returns the identification of the instrument.

**property options**
Requests and returns the device options installed.

**reset()**
Resets the instrument.

**shutdown()**
Brings the instrument to a safe and stable state

**property status**
Requests and returns the status byte and Master Summary Status bit.

## 7.23 Keysight

This section contains specific documentation on the keysight instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.23.1 Keysight DSOX1102G Oscilloscope

**class** pymeasure.instruments.keysight.**KeysightDSOX1102G**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keysight DSOX1102G Oscilloscope interface for interacting with the instrument.

Refer to the Keysight DSOX1102G Oscilloscope Programmer's Guide for further details about using the lower-level methods to interact directly with the scope.

```
scope = KeysightDSOX1102G(resource)
scope.autoscale()
ch1_data_array, ch1_preamble = scope.download_data(source="channel1", points=2000)
# ...
scope.shutdown()
```

Known issues:

- The digitize command will be completed before the operation is. May lead to VI_ERROR_TMO (timeout) occuring when sending commands immediately after digitize. Current fix: if deemed necessary, add delay between digitize and follow-up command to scope.

**property acquisition_mode**
A string parameter that sets the acquisition mode. Can be "realtime" or "segmented".

**property acquisition_type**
A string parameter that sets the type of data acquisition. Can be "normal", "average", "hresolution", or "peak".

**ask**(*command*)
Writes the command to the instrument through the adapter and returns the read response.

**Parameters** **command** – command string to be sent to the instrument

**autoscale**()
Autoscale displayed channels.

**check_errors**()
Read all errors from the instrument.

**Returns** list of error entries

**clear**()
Clears the instrument status byte

**clear_status**()
Clear device status.

**property complete**
This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**static control**(*get_command*, *set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *get_process=<function Instrument.<lambda>>*, *set_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_set_errors=False*, *check_get_errors=False*, *dynamic=False*, ***kwargs*)
Returns a property for the class based on the supplied commands. This property may be set and read from the instrument. See also `measurement()` and `setting()`.

**Parameters**

- **get_command** – A string command that asks for the value, set to *None* if get is not supported (see also `setting()`).
- **set_command** – A string command that writes the value, set to *None* if set is not supported (see also `measurement()`).
- **docs** – A docstring that will be included in the documentation
- **validator** – A function that takes both a value and a group of valid values and returns a valid value, while it otherwise raises an exception
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map

- **get_process** – A function that take a value and allows processing before value mapping, returning the processed value
- **set_process** – A function that takes a value and allows processing before value mapping, returning the processed value
- **command_process** – A function that takes a command and allows processing before executing the command
- **check_set_errors** – Toggles checking errors after setting
- **check_get_errors** – Toggles checking errors after getting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses.

Example of usage of dynamic parameter is as follows:

```
class GenericInstrument(Instrument):
    center_frequency = Instrument.control(
        ":SENS:FREQ:CENT?;", ":SENS:FREQ:CENT %e GHz;",
        " A floating point property that represents the frequency ... ",
        validator=strict_range,
        # Redefine this in subclasses to reflect actual instrument value:
        values=(1, 20),
        dynamic=True  # enable changing property parameters on-the-fly
    )

class SpecificInstrument(GenericInstrument):
    # Identical to GenericInstrument, except for frequency range
    # Override the "values" parameter of the "center_frequency" property
    center_frequency_values = (1, 10) # Redefined at subclass level

instrument = SpecificInstrument()
instrument.center_frequency_values = (1, 6e9) # Redefined at instance level
```

**Warning:** Unexpected side effects when using dynamic properties

Users must pay attention when using dynamic properties, since definition of class and/or instance attributes matching specific patterns could have unwanted side effect. The attribute name pattern *property_param*, where *property* is the name of the dynamic property (e.g. *center_frequency* in the example) and *param* is any of this method parameters name except *dynamic* and *docs* (e.g. *values* in the example) has to be considered reserved for dynamic property control.

**default_setup**()
Default setup, some user settings (like preferences) remain unchanged.

**digitize**(*source: str*)
Acquire waveforms according to the settings of the :ACQuire commands. Ensure a delay between the digitize operation and further commands, as timeout may be reached before digitize has completed. :param source: “channel1”, “channel2”, “function”, “math”, “fft”, “abus”, or “ext”.

**download_data**(*source*, *points=62500*)
Get data from specified source of oscilloscope. Returned objects are a np.ndarray of data values (no temporal axis) and a dict of the waveform preamble, which can be used to build the corresponding time values for all data points.

Multimeter will be stopped for proper acquisition.

**Parameters**

- **source** – measurement source, can be "channel1", "channel2", "function", "fft", "wmemory1", "wmemory2", or "ext".
- **points** – integer number of points to acquire. Note that oscilloscope may return fewer points than specified, this is not an issue of this library. Can be 100, 250, 500, 1000, 2000, 5000, 10000, 20000, 50000, or 62500.

**Return data_ndarray, waveform_preamble_dict** see waveform_preamble property for dict format.

`download_image`(*format_='png'*, *color_palette='color'*)
Get image of oscilloscope screen in bytearray of specified file format.

**Parameters**

- **format** – "bmp", "bmp8bit", or "png"
- **color_palette** – "color" or "grayscale"

`factory_reset`()
Factory default setup, no user settings remain unchanged.

`property id`
Requests and returns the identification of the instrument.

`static measurement`(*get_command*, *docs*, *values=()*, *map_values=None*, *get_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_get_errors=False*, *dynamic=False*, ***kwargs*)
Returns a property for the class based on the supplied commands. This is a measurement quantity that may only be read from the instrument, not set.

**Parameters**

- **get_command** – A string command that asks for the value
- **docs** – A docstring that will be included in the documentation
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map
- **get_process** – A function that take a value and allows processing before value mapping, returning the processed value
- **command_process** – A function that take a command and allows processing before executing the command, for getting
- **check_get_errors** – Toggles checking errors after getting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses. See `control()` for an usage example.

`property options`
Requests and returns the device options installed.

`read`()
Reads from the instrument through the adapter and returns the response.

`reset`()
Resets the instrument.

**run**()
Starts repetitive acquisitions.

This is the same as pressing the Run key on the front panel.

**static setting**(*set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *set_process=<function Instrument.<lambda>>*, *check_set_errors=False*, *dynamic=False*, ***kwargs*)
Returns a property for the class based on the supplied commands. This property may be set, but raises an exception when being read from the instrument.

**Parameters**

- **set_command** – A string command that writes the value
- **docs** – A docstring that will be included in the documentation
- **validator** – A function that takes both a value and a group of valid values and returns a valid value, while it otherwise raises an exception
- **values** – A list, tuple, range, or dictionary of valid values, that can be used as to map values if `map_values` is True.
- **map_values** – A boolean flag that determines if the values should be interpreted as a map
- **set_process** – A function that takes a value and allows processing before value mapping, returning the processed value
- **check_set_errors** – Toggles checking errors after setting
- **dynamic** – Specify whether the property parameters are meant to be changed in instances or subclasses. See `control()` for an usage example.

**shutdown**()
Brings the instrument to a safe and stable state

**single**()
Causes the instrument to acquire a single trigger of data. This is the same as pressing the Single key on the front panel.

**property status**
Requests and returns the status byte and Master Summary Status bit.

**stop**()
Stops the acquisition. This is the same as pressing the Stop key on the front panel.

**property system_setup**
A string parameter that sets up the oscilloscope. Must be in IEEE 488.2 format. It is recommended to only set a string previously obtained from this command.

**property timebase**
Read timebase setup as a dict containing the following keys: - "REF": position on screen of timebase reference (str) - "MAIN:RANG": full-scale timebase range (float) - "POS": interval between trigger and reference point (float) - "MODE": mode (str)

**property timebase_mode**
A string parameter that sets the current time base. Can be "main", "window", "xy", or "roll".

**property timebase_offset**
A float parameter that sets the time interval in seconds between the trigger event and the reference position (at center of screen by default).

**property timebase_range**
A float parameter that sets the full-scale horizontal time in seconds for the main window.

**property timebase_scale**
A float parameter that sets the horizontal scale (units per division) in seconds for the main window.

**timebase_setup**(*mode=None*, *offset=None*, *horizontal_range=None*, *scale=None*)
Set up timebase. Unspecified parameters are not modified. Modifying a single parameter might impact other parameters. Refer to oscilloscope documentation and make multiple consecutive calls to channel_setup if needed.

**Parameters**

- **mode** – Timebase mode, can be "main", "window", "xy", or "roll".
- **offset** – Offset in seconds between trigger and center of screen.
- **horizontal_range** – Full-scale range in seconds.
- **scale** – Units-per-division in seconds.

**values**(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

**property waveform_data**
Get the binary block of sampled data points transmitted using the IEEE 488.2 arbitrary block data format.

**property waveform_format**
A string parameter that controls how the data is formatted when sent from the oscilloscope. Can be "ascii", "word" or "byte". Words are transmitted in big endian by default.

**property waveform_points**
An integer parameter that sets the number of waveform points to be transferred with the waveform_data method. Can be any of the following values: 100, 250, 500, 1000, 2 000, 5 000, 10 000, 20 000, 50 000, 62 500.

Note that the oscilloscope may provide less than the specified nb of points.

**property waveform_points_mode**
A string parameter that sets the data record to be transferred with the waveform_data method. Can be "normal", "maximum", or "raw".

**property waveform_preamble**
Get preamble information for the selected waveform source as a dict with the following keys: - "format": byte, word, or ascii (str) - "type": normal, peak detect, or average (str) - "points": nb of data points transferred (int) - "count": always 1 (int) - "xincrement": time difference between data points (float) - "xorigin": first data point in memory (float) - "xreference": data point associated with xorigin (int) - "yincrement": voltage difference between data points (float) - "yorigin": voltage at center of screen (float) - "yreference": data point associated with yorigin (int)

**property waveform_source**
A string parameter that selects the analog channel, function, or reference waveform to be used as the source for the waveform methods. Can be "channel1", "channel2", "function", "fft", "wmemory1", "wmemory2", or "ext".

**write**(*command*)
Writes the command to the instrument through the adapter.

**Parameters** **command** – command string to be sent to the instrument

### 7.23.2 Keysight N5767A Power Supply

**class** pymeasure.instruments.keysight.**KeysightN5767A**(*adapter*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Keysight N5767A Power supply interface for interacting with the instrument.

**check_errors()**

Read all errors from the instrument.

**Returns** list of error entries

**property complete**

This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**property current**

Reads a setting current in Amps.

**property current_range**

A floating point property that controls the DC current range in Amps, which can take values from 0 to 25 A. Auto-range is disabled when this property is set.

**disable()**

Disables the flow of current.

**enable()**

Enables the flow of current.

**property id**

Requests and returns the identification of the instrument.

**is_enabled()**

Returns True if the current supply is enabled.

**property options**

Requests and returns the device options installed.

**reset()**

Resets the instrument.

**shutdown()**

Brings the instrument to a safe and stable state

**property status**

Requests and returns the status byte and Master Summary Status bit.

**property voltage**

Reads a DC voltage measurement in Volts.

**property voltage_range**

A floating point property that controls the DC voltage range in Volts, which can take values from 0 to 60 V. Auto-range is disabled when this property is set.

### 7.23.3 Keysight N5767A Power Supply

**class** pymeasure.instruments.keysight.**KeysightN7776C**(*address*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

This represents the Keysight N7776C Tunable Laser Source interface.

```
laser = N7776C(address)
laser.sweep_wl_start = 1550
laser.sweep_wl_stop = 1560
laser.sweep_speed = 1
laser.sweep_mode = 'CONT'
laser.output_enabled = 1
while laser.sweep_state == 1:
    log.info('Sweep in progress.')
laser.output_enabled = 0
```

**check_errors**()

Read all errors from the instrument.

**Returns** list of error entries

**close**()

Fully closes the connection to the instrument through the adapter connection.

**property complete**

This property allows synchronization between a controller and a device. The Operation Complete query places an ASCII character 1 into the device's Output Queue when all pending selected device operations have been finished.

**get_wl_data**()

Function returning the wavelength data logged in the internal memory of the laser

**property id**

Requests and returns the identification of the instrument.

**property locked**

Boolean property controlling the lock state (True/False) of the laser source

**next_step**()

Performs the next sweep step in stepped sweep if it is paused or in manual mode.

**property options**

Requests and returns the device options installed.

**property output_enabled**

Boolean Property that controls the state (on/off) of the laser source

**previous_step**()

Performs one sweep step backwards in stepped sweep if its paused or in manual mode.

**reset**()

Resets the instrument.

**shutdown**()

Brings the instrument to a safe and stable state

**property status**

Requests and returns the status byte and Master Summary Status bit.

**property sweep_mode**
Sweep mode of the swept laser source

**property sweep_points**
Returns the number of datapoints that the :READout:DATA? command will return.

**property sweep_speed**
Speed of the sweep (in nanometers per second).

**property sweep_state**
State of the wavelength sweep. Stops, starts, pauses or continues a wavelength sweep. Possible state values are 0 (not running), 1 (running) and 2 (paused). Refer to the N7776C user manual for exact usage of the paused option.

**property sweep_step**
Step width of the sweep (in nanometers).

**property sweep_twoway**
Sets the repeat mode. Applies in stepped,continuous and manual sweep mode.

**property sweep_wl_start**
Start Wavelength (in nanometers) for a sweep.

**property sweep_wl_stop**
End Wavelength (in nanometers) for a sweep.

**property trigger_in**
Sets the incoming trigger response and arms the module.

**property trigger_out**
Specifies if and at which point in a sweep cycle an output trigger is generated and arms the module.

**property wavelength**
Absolute wavelength of the output light (in nanometers)

**property wl_logging**
State (on/off) of the lambda logging feature of the laser source.

## 7.24 Lake Shore Cryogenics

This section contains specific documentation on the Lake Shore Cryogenics instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.24.1 Lake Shore Adapters

**class** pymeasure.instruments.lakeshore.**LakeShoreUSBAdapter**(*port*)
Bases: `pymeasure.adapters.serial.SerialAdapter`

Provides a `SerialAdapter` with the specific baudrate, timeout, parity, and byte size for LakeShore USB communication.

Initiates the adapter to open serial communcation over the supplied port.

**Parameters** **port** – A string representing the serial port

**_format_binary_values**(*values*, *datatype='f'*, *is_big_endian=False*, *header_fmt='ieee'*)
Format values in binary format, used internally in `write_binary_values()`.

**Parameters**

- **values** – data to be written to the device.
- **datatype** – the format string for a single element. See struct module.
- **is_big_endian** – boolean indicating endianess.
- **header_fmt** – Format of the header prefixing the data ("ieee", "hp", "empty").

**Returns** binary string.

**Return type** bytes

**ask**(*command*)
Writes the command to the instrument and returns the resulting ASCII response

**Parameters** **command** – SCPI command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**binary_values**(*command*, *header_bytes=0*, *dtype=<class 'numpy.float32'>*)
Returns a numpy array from a query for binary data

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header
- **dtype** – The NumPy data type to format the values with

**Returns** NumPy array of values

**read**()
Reads until the buffer is empty and returns the resulting ASCII response

**Returns** String ASCII response of the instrument.

**values**(*command*, *separator=', '*, *cast=<class 'float'>*, *preprocess_reply=None*)
Writes a command to the instrument and returns a list of formatted values from the result

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **separator** – A separator character to split the string into a list
- **cast** – A type to cast the result
- **preprocess_reply** – optional callable used to preprocess values received from the instrument. The callable returns the processed string. If not specified, the Adapter default is used if available, otherwise no preprocessing is done.

**Returns** A list of the desired type, or strings where the casting fails

**write**(*command*)
Overwrites the `SerialAdapter.write` method to automatically append a Unix-style linebreak at the end of the command.

**Parameters** **command** – SCPI command string to be sent to the instrument

**write_binary_values**(*command*, *values*, ***kwargs*)
Write binary data to the instrument, e.g. waveform for signal generators

**Parameters**

- **command** – SCPI command to be sent to the instrument
- **values** – iterable representing the binary values

- **kwargs** – Key-word arguments to pass onto *_format_binary_values()*

**Returns** number of bytes written

### 7.24.2 Lake Shore 331 Temperature Controller

**class** pymeasure.instruments.lakeshore.**LakeShore331**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Lake Shore 331 Temperature Controller and provides a high-level interface for interacting with the instrument.

```
controller = LakeShore331("GPIB::1")

print(controller.setpoint_1)        # Print the current setpoint for loop 1
controller.setpoint_1 = 50          # Change the setpoint to 50 K
controller.heater_range = 'low'     # Change the heater range to Low
controller.wait_for_temperature()   # Wait for the temperature to stabilize
print(controller.temperature_A)     # Print the temperature at sensor A
```

**disable_heater**()

Turns the *heater_range* to off to disable the heater.

**property heater_range**

A string property that controls the heater range, which can take the values: off, low, medium, and high. These values correlate to 0, 0.5, 5 and 50 W respectively.

**property setpoint_1**

A floating point property that controls the setpoint temperature in Kelvin for Loop 1.

**property setpoint_2**

A floating point property that controls the setpoint temperature in Kelvin for Loop 2.

**property temperature_A**

Reads the temperature of the sensor A in Kelvin.

**property temperature_B**

Reads the temperature of the sensor B in Kelvin.

**wait_for_temperature**(*accuracy=0.1*, *interval=0.1*, *sensor='A'*, *setpoint=1*, *timeout=360*, *should_stop=<function LakeShore331.<lambda>>*)

Blocks the program, waiting for the temperature to reach the setpoint within the accuracy (%), checking this each interval time in seconds.

**Parameters**

- **accuracy** – An acceptable percentage deviation between the setpoint and temperature
- **interval** – A time in seconds that controls the refresh rate
- **sensor** – The desired sensor to read, either A or B
- **setpoint** – The desired setpoint loop to read, either 1 or 2
- **timeout** – A timeout in seconds after which an exception is raised
- **should_stop** – A function that returns True if waiting should stop, by default this always returns False

### 7.24.3 Lake Shore 421 Gaussmeter

**class** pymeasure.instruments.lakeshore.**LakeShore421**(*resource_name*, *baud_rate=9600*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Lake Shore 421 Gaussmeter and provides a high-level interface for interacting with the instrument. .. code-block:: python

gaussmeter = LakeShore421("COM1") gaussmeter.unit = "T" # Set units to Tesla gaussmeter.auto_range = True # Turn on auto-range gaussmeter.fast_mode = True # Turn on fast-mode

A delay of 50 ms is ensured between subsequent writes, as the instrument cannot correctly handle writes any faster.

**property alarm_active**
A boolean property that returns whether the alarm is triggered.

**property alarm_audible**
A boolean property that enables or disables the audible alarm beeper.

**property alarm_high**
Property that controls the upper setpoint for the alarm mode in the current units. This takes into account the field multiplier.

**property alarm_high_multiplier**
Returns the multiplier for the upper alarm setpoint field.

**property alarm_high_raw**
ALMH %g

**property alarm_in_out**
A string property that controls whether an active alarm is caused when the field reading is inside ("Inside") or outside ("Outside") of the high and low setpoint values.

**property alarm_low**
Property that controls the lower setpoint for the alarm mode in the current units. This takes into account the field multiplier.

**property alarm_low_multiplier**
Returns the multiplier for the lower alarm setpoint field.

**property alarm_low_raw**
ALML %g

**property alarm_mode_enabled**
A boolean property that enables or disables the alarm mode.

**property alarm_sort_enabled**
A boolean property that enables or disables the alarm Sort Pass/Fail function.

**ask**(*command*)
Writes the command to the instrument through the adapter and returns the read response.

**Parameters** **command** – command string to be sent to the instrument

**property auto_range**
A boolean property that controls the auto-range option of the meter. Valid values are True and False. Note that the auto-range is relatively slow and might not suffice for rapid measurements.

**property display_filter_enabled**
A boolean property that controls the display filter to make it more readable when the probe is exposed to a noisy field. The filter function makes a linear average of 8 readings and settles in approximately 2 seconds.

**property fast_mode**
A boolean property that controls the fast-mode option of the meter. Valid values are True and False. When enabled, the relative mode, Max Hold mode, alarms, and autorange are disabled.

**property field**
Returns the field in the current units. This property takes into account the field multiplier. Returns np.nan if field is out of range.

**property field_mode**
A string property that controls whether the gaussmeter measures AC or DC magnetic fields. Valid values are "AC" and "DC".

**property field_multiplier**
Returns the field multiplier for the returned magnetic field.

**property field_range**
A floating point property that controls the field range of the meter in the current unit (G or T). Valid values are 30e3, 3e3, 300, 30 (when in Gauss), or 0.003, 0.03, 0.3, and 3 (when in Tesla).

**property field_range_raw**
A integer property that controls the field range of the meter. Valid values are 0 (highest) to 3 (lowest).

**property field_raw**
Returns the field in the current units and multiplier

**property front_panel_brightness**
An integer property that controls the brightness of the from panel display. Valid values are 0 (dimmest) to 7 (brightest).

**property front_panel_locked**
A boolean property that locks or unlocks all front panel entries except pressing the Alarm key to silence alarms.

**property max_hold_enabled**
A boolean property that enables or disables the Max Hold function to store the largest field since the last reset (with max_hold_reset).

**property max_hold_field**
Returns the largest field since the last reset in the current units. This property takes into account the field multiplier. Returns np.nan if field is out of range.

**property max_hold_field_raw**
Returns the largest field since the last reset in the current units and multiplier.

**property max_hold_multiplier**
Returns the multiplier for the returned max hold field.

**max_hold_reset()**
Clears the stored Max Hold value.

**property probe_type**
Returns type of field-probe used with the gaussmeter. Possible values are High Sensitivity, High Stability, or Ultra-High Sensitivity.

**property relative_field**
Returns the relative field in the current units. This property takes into account the field multiplier. Returns np.nan if field is out of range.

**property relative_field_raw**
Returns the relative field in the current units and the current multiplier.

**property relative_mode_enabled**
A boolean property that enables or disables the relative mode to see small variations with respect to a given setpoint.

**property relative_multiplier**
Returns the relative field multiplier for the returned magnetic field.

**property relative_setpoint**
Property that controls the setpoint for the relative field mode in the current units. This takes into account the field multiplier.

**property relative_setpoint_multiplier**
Returns the multiplier for the setpoint field.

**property relative_setpoint_raw**
Property that controls the setpoint for the relative field mode in the current units and multiplier.

**property serial_number**
Returns the serial number of the probe.

**shutdown()**
Closes the serial connection to the system.

**property unit**
A string property that controls the units used by the gaussmeter. Valid values are G (Gauss), T (Tesla).

**values**(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

**write**(*command*)
Writes the command to the instrument through the adapter.

**Parameters** **command** – command string to be sent to the instrument

**zero_probe**(*wait=True*)
Reset the probe value to 0. It is normally used with a zero gauss chamber, but may also be used with an open probe to cancel the Earth magnetic field. To cancel larger magnetic fields, the relative mode should be used.

**Parameters** **wait** (`bool`) – Wait for 20 seconds after issuing the command to allow the resetting to finish.

### 7.24.4 Lake Shore 425 Gaussmeter

**class** pymeasure.instruments.lakeshore.**LakeShore425**(*port*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the LakeShore 425 Gaussmeter and provides a high-level interface for interacting with the instrument

To allow user access to the LakeShore 425 Gaussmeter in Linux, create the file: `/etc/udev/rules.d/52-lakeshore425.rules`, with contents:

```
SUBSYSTEMS=="usb",ATTRS{idVendor}=="1fb9",ATTRS{idProduct}=="0401",MODE="0666",
↪SYMLINK+="lakeshore425"
```

Then reload the udev rules with:

```
sudo udevadm control --reload-rules
sudo udevadm trigger
```

The device will be accessible through `/dev/lakeshore425`.

**ac_mode**(*wideband=True*)
Sets up a measurement of an oscillating (AC) field

**auto_range**()
Sets the field range to automatically adjust

**dc_mode**(*wideband=True*)
Sets up a steady-state (DC) measurement of the field

**property field**
Returns the field in the current units

**measure**(*points*, *has_aborted=<function LakeShore425.<lambda>>*, *delay=0.001*)
Returns the mean and standard deviation of a given number of points while blocking

**property range**
A floating point property that controls the field range in units of Gauss, which can take the values 35, 350, 3500, and 35,000 G.

**property unit**
A string property that controls the units of the instrument, which can take the values of G, T, Oe, or A/m.

**zero_probe**()
Initiates the zero field sequence to calibrate the probe

## 7.25 Newport

This section contains specific documentation on the Newport instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.25.1 ESP 300 Motion Controller

**class** pymeasure.instruments.newport.**ESP300**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Newport ESP 300 Motion Controller and provides a high-level for interacting with the instrument.

By default this instrument is constructed with x, y, and phi attributes that represent axes 1, 2, and 3. Custom implementations can overwrite this depending on the avalible axes. Axes are controlled through an `Axis` class.

**property axes**
A list of the `Axis` objects that are present.

**clear_errors**()
Clears the error messages by checking until a 0 code is recived.

**disable**()
Disables all of the axes associated with this controller.

**enable**()
Enables all of the axes associated with this controller.

**property error**
Reads an error code from the motion controller.

**property errors**
Returns a list of error Exceptions that can be later raised, or used to diagnose the situation.

**shutdown**()
: Shuts down the controller by disabling all of the axes.

class pymeasure.instruments.newport.esp300.**Axis**(*axis*, *controller*)
: Bases: object

  Represents an axis of the Newport ESP300 Motor Controller, which can have independent parameters from the other axes.

  **define_position**(*position*)
  : Overwrites the value of the current position with the given value.

  **disable**()
  : Disables motion for the axis.

  **enable**()
  : Enables motion for the axis.

  property **enabled**
  : Returns a boolean value that is True if the motion for this axis is enabled.

  **home**(*type=1*)
  : Drives the axis to the home position, which may be the negative hardware limit for some actuators (e.g. LTA-HS). type can take integer values from 0 to 6.

  property **left_limit**
  : A floating point property that controls the left software limit of the axis.

  property **motion_done**
  : Returns a boolean that is True if the motion is finished.

  property **position**
  : A floating point property that controls the position of the axis. The units are defined based on the actuator. Use the `wait_for_stop()` method to ensure the position is stable.

  property **right_limit**
  : A floating point property that controls the right software limit of the axis.

  property **units**
  : A string property that controls the displacement units of the axis, which can take values of: enconder count, motor step, millimeter, micrometer, inches, milli-inches, micro-inches, degree, gradient, radian, milliradian, and microradian.

  **wait_for_stop**(*delay=0*, *interval=0.05*)
  : Blocks the program until the motion is completed. A further delay can be specified in seconds.

  **zero**()
  : Resets the axis position to be zero at the current poisiton.

class pymeasure.instruments.newport.esp300.**AxisError**(*code*)
: Bases: Exception

  Raised when a particular axis causes an error for the Newport ESP300.

class pymeasure.instruments.newport.esp300.**GeneralError**(*code*)
: Bases: Exception

  Raised when the Newport ESP300 has a general error.

## 7.26 National Instruments

This section contains specific documentation on the National Instruments instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.26.1 NI Virtual Bench

#### General Information

The armstrap/pyvirtualbench Python wrapper for the VirtualBench C-API is required. This Instrument driver only interfaces the pyvirtualbench Python wrapper.

#### Examples

To be documented. Check the examples in the pyvirtualbench repository to get an idea.

Simple Example to switch digital lines of the DIO module.

```
from pymeasure.instruments.ni import VirtualBench

vb = VirtualBench(device_name='VB8012-3057E1C')
line = 'dig/2'  # may be list of lines
# initialize DIO module -> available via vb.dio
vb.acquire_digital_input_output(line, reset=False)

vb.dio.write(self.line, {True})
sleep(1000)
vb.dio.write(self.line, {False})

vb.shutdown()
```

#### Instrument Class

**class** pymeasure.instruments.ni.virtualbench.**VirtualBench**(*device_name=''*, *name='VirtualBench'*)

Bases: `object`

Represents National Instruments Virtual Bench main frame.

Subclasses implement the functionalities of the different modules:

- Mixed-Signal-Oscilloscope (MSO)
- Digital Input Output (DIO)
- Function Generator (FGEN)
- Power Supply (PS)
- Serial Peripheral Interface (SPI) -> not implemented for pymeasure yet
- Inter Integrated Circuit (I2C) -> not implemented for pymeasure yet

For every module exist methods to save/load the configuration to file. These methods are not wrapped so far, checkout the pyvirtualbench file.

All calibration methods and classes are not wrapped so far, since these are not required on a very regular basis. Also the connections via network are not yet implemented. Check the pyvirtualbench file, if you need the functionality.

**Parameters**

- **device_name** (*str*) – Full unique device name
- **name** (*str*) – Name for display in pymeasure

`class DigitalInputOutput`(*virtualbench*, *lines*, *reset*, *vb_name=''*)

Bases: `pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument`

Represents Digital Input Output (DIO) Module of Virtual Bench device. Allows to read/write digital channels and/or set channels to export the start signal of FGEN module or trigger of MSO module.

`export_signal`(*line*, *digitalSignalSource*)

Exports a signal to the specified line.

**Parameters**

- **line** (*str*) – Line string
- **digitalSignalSource** (*int*) – `0` for FGEN start or 1 for MSO trigger

`query_export_signal`(*line*)

Indicates the signal being exported on the specified line.

**Parameters** **line** (*str*) – Line string

**Returns** Exported signal (FGEN start or MSO trigger)

**Return type** enum

`query_line_configuration`()

Indicates the current line configurations. Tristate Lines, Static Lines, and Export Lines contain comma-separated range_data and/or colon-delimited lists of all acquired lines

`read`(*lines*)

Reads the current state of the specified lines.

**Parameters** **lines** (*str*) – Line string, requires full name specification e.g. `'VB8012-xxxxxxx/dig/0:7'` since instrument_handle is not required (only library_handle)

**Returns** List of line states (HIGH/LOW)

**Return type** list

`reset_instrument`()

Resets the session configuration to default values, and resets the device and driver software to a known state.

`shutdown`()

Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

`tristate_lines`(*lines*)

Sets all specified lines to a high-impedance state. (Default)

`validate_lines`(*lines*, *return_single_lines=False*, *validate_init=False*)

Validate lines string Allowed patterns (case sensitive):

- `'VBxxxx-xxxxxxx/dig/0:7'`
- `'VBxxxx-xxxxxxx/dig/0'`
- `'dig/0'`
- `'VBxxxx-xxxxxxx/trig'`
- `'trig'`

Allowed Line Numbers: 0-7 or trig

**Parameters**

- `lines` (*str*) – Line string to test
- `return_single_lines` (*bool, optional*) – Return list of line numbers as well, defaults to False
- `validate_init` (*bool, optional*) – Check if lines are initialized (in `self._line_numbers`), defaults to False

**Returns** Line string, optional list of single line numbers

**Return type** str, optional (str, list)

`write`(*lines*, *data*)

Writes data to the specified lines.

**Parameters**

- `lines` (*str*) – Line string
- `data` (*list or tuple*) – List of data, (`True` = High, `False` = Low)

**class DigitalMultimeter**(*virtualbench*, *reset*, *vb_name=''*)

Bases: `pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument`

Represents Digital Multimeter (DMM) Module of Virtual Bench device. Allows to measure either DC/AC voltage or current, Resistance or Diodes.

`configure_ac_current`(*auto_range_terminal*)

Configure auto rage terminal for AC current measurement

**Parameters** `auto_range_terminal` – Terminal to perform auto ranging (`'LOW'` or `'HIGH'`)

`configure_dc_current`(*auto_range_terminal*)

Configure auto rage terminal for DC current measurement

**Parameters** `auto_range_terminal` – Terminal to perform auto ranging (`'LOW'` or `'HIGH'`)

`configure_dc_voltage`(*dmm_input_resistance*)

Configure DC voltage input resistance

**Parameters** `dmm_input_resistance` (*int or str*) – Input resistance (`'TEN_MEGA_OHM'` or `'TEN_GIGA_OHM'`)

`configure_measurement`(*dmm_function*, *auto_range=True*, *manual_range=1.0*)

Configure Instrument to take a DMM measurement

**Parameters**

- `name` (*dmm_function:DMM function index or*) –
  - `'DC_VOLTS'`, `'AC_VOLTS'`
  - `'DC_CURRENT'`, `'AC_CURRENT'`
  - `'RESISTANCE'`
  - `'DIODE'`
- `auto_range` (*bool*) – Enable/Disable auto ranging
- `manual_range` (*float*) – Manually set measurement range

`query_ac_current`()

Indicates auto range terminal for AC current measurement

`query_dc_current`()

Indicates auto range terminal for DC current measurement

`query_dc_voltage`()

Indicates input resistance setting for DC voltage measurement

`query_measurement`()

Query DMM measurement settings from the instrument

**Returns** Auto range, range data

**Return type** (bool, float)

`read()`

Read measurement value from the instrument

**Returns** Measurement value

**Return type** float

`reset_instrument()`

Reset the DMM module to defaults

`shutdown()`

Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

`validate_auto_range_terminal`(*auto_range_terminal*)

Check value for choosing the auto range terminal for DC current measurement

**Parameters** **auto_range_terminal** (*int or str*) – Terminal to perform auto ranging (`'LOW'` or `'HIGH'`)

**Returns** Auto range terminal to pass to the instrument

**Return type** int

`validate_dmm_function`(*dmm_function*)

Check if DMM function *dmm_function* exists

**Parameters** **dmm_function** (*int or str*) – DMM function index or name:

- `'DC_VOLTS'`, `'AC_VOLTS'`
- `'DC_CURRENT'`, `'AC_CURRENT'`
- `'RESISTANCE'`
- `'DIODE'`

**Returns** DMM function index to pass to the instrument

**Return type** int

`static validate_range`(*dmm_function*, *range*)

Checks if `range` is valid for the chosen `dmm_function`

**Parameters**

- **dmm_function** (*int*) – DMM Function
- **range** (*int or float*) – Range value, e.g. maximum value to measure

**Returns** Range value to pass to instrument

**Return type** int

`class FunctionGenerator`(*virtualbench*, *reset*, *vb_name=''*)

Bases: `pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument`

Represents Function Generator (FGEN) Module of Virtual Bench device.

`configure_arbitrary_waveform`(*waveform*, *sample_period*)

Configures the instrument to output a waveform. The waveform is output either after the end of the current waveform if output is enabled, or immediately after output is enabled.

**Parameters**

- **waveform** (*list*) – Waveform as list of values

- **sample_period** (*float*) – Time between two waveform points (maximum of 125MS/s, which equals 80ns)

**configure_arbitrary_waveform_gain_and_offset**(*gain*, *dc_offset*)
Configures the instrument to output an arbitrary waveform with a specified gain and offset value. The waveform is output either after the end of the current waveform if output is enabled, or immediately after output is enabled.

**Parameters**

- **gain** (*float*) – Gain, multiplier of waveform values
- **dc_offset** (*float*) – DC offset in volts

**configure_standard_waveform**(*waveform_function*, *amplitude*, *dc_offset*, *frequency*, *duty_cycle*)
Configures the instrument to output a standard waveform. Check instrument manual for maximum ratings which depend on load.

**Parameters**

- **waveform_function** (*int or str*) – Waveform function ("SINE", "SQUARE", "TRIANGLE/RAMP", "DC")
- **amplitude** (*float*) – Amplitude in volts
- **dc_offset** (*float*) – DC offset in volts
- **frequency** (*float*) – Frequency in Hz
- **duty_cycle** (*int*) – Duty cycle in %

**property filter**
Enables or disables the filter on the instrument.

**Parameters** **enable_filter** (*bool*) – Enable/Disable filter

**query_arbitrary_waveform**()
Returns the samples per second for arbitrary waveform generation.

**Returns** Samples per second

**Return type** int

**query_arbitrary_waveform_gain_and_offset**()
Returns the settings for arbitrary waveform generation that includes gain and offset settings.

**Returns** Gain, DC offset

**Return type** (float, float)

**query_generation_status**()
Returns the status of waveform generation on the instrument.

**Returns** Status

**Return type** enum

**query_standard_waveform**()
Returns the settings for a standard waveform generation.

**Returns** Waveform function, amplitude, dc_offset, frequency, duty_cycle

**Return type** (enum, float, float, float, int)

**query_waveform_mode**()
Indicates whether the waveform output by the instrument is a standard or arbitrary waveform.

**Returns** Waveform mode

**Return type** enum

`reset_instrument()`
Resets the session configuration to default values, and resets the device and driver software to a known state.

`run()`
Transitions the session from the Stopped state to the Running state.

`self_calibrate()`
Performs offset nulling calibration on the device. You must run FGEN Initialize prior to running this method.

`shutdown()`
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

`stop()`
Transitions the acquisition from either the Triggered or Running state to the Stopped state.

**class MixedSignalOscilloscope**(*virtualbench*, *reset*, *vb_name=''*)
Bases: `pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument`

Represents Mixed Signal Oscilloscope (MSO) Module of Virtual Bench device. Allows to measure oscilloscope data from analog and digital channels.

Methods from pyvirtualbench not implemented in pymeasure yet:

- `enable_digital_channels`
- `configure_digital_threshold`
- `configure_advanced_digital_timing`
- `configure_state_mode`
- `configure_digital_edge_trigger`
- `configure_digital_pattern_trigger`
- `configure_digital_glitch_trigger`
- `configure_digital_pulse_width_trigger`
- `query_digital_channel`
- `query_enabled_digital_channels`
- `query_digital_threshold`
- `query_advanced_digital_timing`
- `query_state_mode`
- `query_digital_edge_trigger`
- `query_digital_pattern_trigger`
- `query_digital_glitch_trigger`
- `query_digital_pulse_width_trigger`
- `read_digital_u64`

`auto_setup()`
Automatically configure the instrument

**configure_analog_channel**(*channel*, *enable_channel*, *vertical_range*, *vertical_offset*, *probe_attenuation*, *vertical_coupling*)

Configure analog measurement channel

**Parameters**

- **channel** (*str*) – Channel string
- **enable_channel** (*bool*) – Enable/Disable channel
- **vertical_range** (*float*) – Vertical measurement range (0V - 20V), the instrument discretizes to these ranges: `[20, 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05]` which are 5x the values shown in the native UI.
- **vertical_offset** (*float*) – Vertical offset to correct for (inverted compared to VB native UI, -20V - +20V, resolution 0.1mV)
- **probe_attenuation** (*int or str*) – Probe attenuation (`'ATTENUATION_10X'` or `'ATTENUATION_1X'`)
- **vertical_coupling** (*int or str*) – Vertical coupling (`'AC'` or `'DC'`)

**configure_analog_channel_characteristics**(*channel*, *input_impedance*, *bandwidth_limit*)

Configure electrical characteristics of the specified channel

**Parameters**

- **channel** (*str*) – Channel string
- **input_impedance** (*int or str*) – Input Impedance (`'ONE_MEGA_OHM'` or `'FIFTY_OHMS'`)
- **bandwidth_limit** (*int*) – Bandwidth limit (100MHz or 20MHz)

**configure_analog_edge_trigger**(*trigger_source*, *trigger_slope*, *trigger_level*, *trigger_hysteresis*, *trigger_instance*)

Configures a trigger to activate on the specified source when the analog edge reaches the specified levels.

**Parameters**

- **trigger_source** (*str*) – Channel string
- **trigger_slope** (*int or str*) – Trigger slope (`'RISING'`, `'FALLING'` or `'EITHER'`)
- **trigger_level** (*float*) – Trigger level
- **trigger_hysteresis** (*float*) – Trigger hysteresis
- **trigger_instance** (*int or str*) – Trigger instance

**configure_analog_pulse_width_trigger**(*trigger_source*, *trigger_polarity*, *trigger_level*, *comparison_mode*, *lower_limit*, *upper_limit*, *trigger_instance*)

Configures a trigger to activate on the specified source when the analog edge reaches the specified levels within a specified window of time.

**Parameters**

- **trigger_source** (*str*) – Channel string
- **trigger_polarity** (*int or str*) – Trigger slope (`'POSITIVE'` or `'NEGATIVE'`)
- **trigger_level** (*float*) – Trigger level

- **comparison_mode** (*int or str*) – Mode of compariosn ( 'GREATER_THAN_UPPER_LIMIT', 'LESS_THAN_LOWER_LIMIT', 'INSIDE_LIMITS' or 'OUTSIDE_LIMITS')
- **lower_limit** (*float*) – Lower limit
- **upper_limit** (*float*) – Upper limit
- **trigger_instance** (*int or str*) – Trigger instance

`configure_immediate_trigger()`
Configures a trigger to immediately activate on the specified channels after the pretrigger time has expired.

`configure_timing(`*sample_rate*, *acquisition_time*, *pretrigger_time*, *sampling_mode*`)`
Configure timing settings of the MSO

**Parameters**

- **sample_rate** (*int*) – Sample rate (15.26kS - 1GS)
- **acquisition_time** (*float*) – Acquisition time (1ns - 68.711s)
- **pretrigger_time** (*float*) – Pretrigger time (0s - 10s)
- **sampling_mode** – Sampling mode ('SAMPLE' or 'PEAK_DETECT')

`configure_trigger_delay(`*trigger_delay*`)`
Configures the amount of time to wait after a trigger condition is met before triggering.

**param float trigger_delay** Trigger delay (0s - 17.1799s)

`force_trigger()`
Causes a software-timed trigger to occur after the pretrigger time has expired.

`query_acquisition_status()`
Returns the status of a completed or ongoing acquisition.

`query_analog_channel(`*channel*`)`
Indicates the vertical configuration of the specified channel.

**Returns** Channel enabled, vertical range, vertical offset, probe attenuation, vertical coupling

**Return type** (bool, float, float, enum, enum)

`query_analog_channel_characteristics(`*channel*`)`
Indicates the properties that control the electrical characteristics of the specified channel. This method returns an error if too much power is applied to the channel.

**return** Input impedance, bandwidth limit

**rtype** (enum, float)

`query_analog_edge_trigger(`*trigger_instance*`)`
Indicates the analog edge trigger configuration of the specified instance.

**Returns** Trigger source, trigger slope, trigger level, trigger hysteresis

**Return type** (str, enum, float, float)

`query_analog_pulse_width_trigger(`*trigger_instance*`)`
Indicates the analog pulse width trigger configuration of the specified instance.

**Returns** Trigger source, trigger polarity, trigger level, comparison mode, lower limit, upper limit

**Return type** (str, enum, float, enum, float, float)

`query_enabled_analog_channels()`
Returns String of enabled analog channels.

**Returns** Enabled analog channels

**Return type** str

`query_timing()`
Indicates the timing configuration of the MSO. Call directly before measurement to read the actual timing configuration and write it to the corresponding class variables. Necessary to interpret the measurement data, since it contains no time information.

**Returns** Sample rate, acquisition time, pretrigger time, sampling mode

**Return type** (float, float, float, enum)

`query_trigger_delay()`
Indicates the trigger delay setting of the MSO.

**Returns** Trigger delay

**Return type** float

`query_trigger_type(`*trigger_instance*`)`
Indicates the trigger type of the specified instance.

**Parameters** **trigger_instance** – Trigger instance (`'A'` or `'B'`)

**Returns** Trigger type

**Return type** str

`read_analog_digital_dataframe()`
Transfers data from the instrument and returns a pandas dataframe of the analog measurement data, including time coordinates

**Returns** Dataframe with time and measurement data

**Return type** pd.DataFrame

`read_analog_digital_u64()`
Transfers data from the instrument as long as the acquisition state is Acquisition Complete. If the state is either Running or Triggered, this method will wait until the state transitions to Acquisition Complete. If the state is Stopped, this method returns an error.

**Returns** Analog data out, analog data stride, analog t0, digital data out, digital timestamps out, digital t0, trigger timestamp, trigger reason

**Return type** (list, int, pyvb.Timestamp, list, list, pyvb.Timestamp, pyvb.Timestamp, enum)

`reset_instrument()`
Resets the session configuration to default values, and resets the device and driver software to a known state.

`run(`*autoTrigger=True*`)`
Transitions the acquisition from the Stopped state to the Running state. If the current state is Triggered, the acquisition is first transitioned to the Stopped state before transitioning to the Running state. This method returns an error if too much power is applied to any enabled channel.

**Parameters** **autoTrigger** (*bool*) – Enable/Disable auto triggering

`shutdown()`
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

`stop()`
Transitions the acquisition from either the Triggered or Running state to the Stopped state.

`validate_channel`(*channel*)
Check if `channel` is a correct specification

**Parameters** **channel** (*str*) – Channel string

**Returns** Channel string

**Return type** str

`static validate_trigger_instance`(*trigger_instance*)
Check if `trigger_instance` is a valid choice

**Parameters** **trigger_instance** (*int or str*) – Trigger instance (`'A'` or `'B'`)

**Returns** Trigger instance

**Return type** int

`class PowerSupply`(*virtualbench*, *reset*, *vb_name=''*)
Bases: `pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument`

Represents Power Supply (PS) Module of Virtual Bench device

`configure_current_output`(*channel*, *current_level*, *voltage_limit*)
Configures a current output on the specified channel. This method should be called once for every channel you want to configure to output current.

`configure_voltage_output`(*channel*, *voltage_level*, *current_limit*)
Configures a voltage output on the specified channel. This method should be called once for every channel you want to configure to output voltage.

`property outputs_enabled`
Enables or disables all outputs on all channels of the instrument.

**Parameters** **enable_outputs** (*bool*) – Enable/Disable outputs

`query_current_output`(*channel*)
Indicates the current output settings on the specified channel.

`query_voltage_output`(*channel*)
Indicates the voltage output settings on the specified channel.

`read_output`(*channel*)
Reads the voltage and current levels and outout mode of the specified channel.

`reset_instrument()`
Resets the session configuration to default values, and resets the device and driver software to a known state.

`shutdown()`
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

`property tracking`
Enables or disables tracking between the positive and negative 25V channels. If enabled, any configuration change on the positive 25V channel is mirrored to the negative 25V channel, and any writes to the negative 25V channel are ignored.

**Parameters** `enable_tracking` (*bool*) – Enable/Disable tracking

`validate_channel`(*channel*, *current=False*, *voltage=False*)
Check if channel string is valid and if output current/voltage are within the output ranges of the channel

**Parameters**

- `channel` (*str*) – Channel string (`"ps/+6V","ps/+25V","ps/-25V"`)
- `current` (*bool, optional*) – Current output, defaults to False
- `voltage` (*bool, optional*) – Voltage output, defaults to False

**Returns** channel or channel, current & voltage

**Return type** str or (str, float, float)

`acquire_digital_input_output`(*lines*, *reset=False*)
Establishes communication with the DIO module. This method should be called once per session.

**Parameters**

- `lines` (*str*) – Lines to acquire, reading is possible on all lines
- `reset` (*bool, optional*) – Reset DIO module, defaults to False

`acquire_digital_multimeter`(*reset=False*)
Establishes communication with the DMM module. This method should be called once per session.

**Parameters** `reset` (*bool, optional*) – Reset the DMM module, defaults to False

`acquire_function_generator`(*reset=False*)
Establishes communication with the FGEN module. This method should be called once per session.

**Parameters** `reset` (*bool, optional*) – Reset the FGEN module, defaults to False

`acquire_mixed_signal_oscilloscope`(*reset=False*)
Establishes communication with the MSO module. This method should be called once per session.

**Parameters** `reset` (*bool, optional*) – Reset the MSO module, defaults to False

`acquire_power_supply`(*reset=False*)
Establishes communication with the PS module. This method should be called once per session.

**Parameters** `reset` (*bool, optional*) – Reset the PS module, defaults to False

`collapse_channel_string`(*names_in*)
Collapses a channel string into a comma and colon-delimited equivalent. Last element is the number of channels.

**Parameters** `names_in` (*str*) – Channel string

**Returns** Channel string with colon notation where possible, number of channels

**Return type** (str, int)

`convert_timestamp_to_values`(*timestamp*)
Converts a timestamp to seconds and fractional seconds

**Parameters** `timestamp` (*pyvb.Timestamp*) – VirtualBench timestamp

**Returns** (seconds_since_1970, fractional seconds)

**Return type** (int, float)

`convert_values_to_datetime`(*timestamp*)
Converts timestamp to datetime object

**Parameters** **timestamp** (*pyvb.Timestamp*) – VirtualBench timestamp

**Returns** Timestamp as DateTime object

**Return type** DateTime

**convert_values_to_timestamp**(*seconds_since_1970*, *fractional_seconds*)
Converts seconds and fractional seconds to a timestamp

**Parameters**

- **seconds_since_1970** (*int*) – Date/Time in seconds since 1970
- **fractional_seconds** (*float*) – Fractional seconds

**Returns** VirtualBench timestamp

**Return type** pyvb.Timestamp

**expand_channel_string**(*names_in*)
Expands a channel string into a comma-delimited (no colon) equivalent. Last element is the number of channels. `'dig/0:2' -> ('dig/0, dig/1, dig/2',3)`

**Parameters** **names_in** (*str*) – Channel string

**Returns** Channel string with all channels separated by comma, number of channels

**Return type** (str, int)

**get_calibration_information**()
Returns calibration information for the specified device, including the last calibration date and calibration interval.

**Returns** Calibration date, recommended calibration interval in months, calibration interval in months

**Return type** (pyvb.Timestamp, int, int)

**get_library_version**()
Return the version of the VirtualBench runtime library

**shutdown**()
Finalize the VirtualBench library.

class pymeasure.instruments.ni.virtualbench.**VirtualBench_Direct**(**args: Any*, ***kwargs: Any*)
Bases: `pyvirtualbench.PyVirtualBench`

Represents National Instruments Virtual Bench main frame. This class provides direct access to the armstrap/pyvirtualbench Python wrapper.

## 7.27 Oxford Instruments

This section contains specific documentation on the Oxford Instruments instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.27.1 Oxford Instruments VISA Adapter

**class** pymeasure.instruments.oxfordinstruments.**OxfordInstrumentsAdapter**(*resource_name*, *max_attempts=5*, ***kwargs*)

Bases: `pymeasure.adapters.visa.VISAAdapter`

Adapter class for the VISA library using PyVISA to communicate with instruments. Checks the replies from instruments for validity.

**Parameters**

- **resource_name** – VISA resource name that identifies the address
- **max_attempts** – Integer that sets how many attempts at getting a valid response to a query can be made
- **kwargs** – key-word arguments for constructing a PyVISA Adapter

**ask**(*command*)

Write the command to the instrument and return the resulting ASCII response. Also check the validity of the response before returning it; if the response is not valid, another attempt is made at getting a valid response, until the maximum amount of attempts is reached.

**Parameters** **command** – ASCII command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**Raises** `OxfordVISAError` if the maximum number of attempts is surpassed without getting a valid response

**is_valid_response**(*response*, *command*)

Check if the response received from the instrument after a command is valid and understood by the instrument.

**Parameters**

- **response** – String ASCII response of the device
- **command** – command used in the initial query

**Returns** True if the response is valid and the response indicates the instrument recognised the command

**write**(*command*)

Write command to instrument and check whether the reply indicates that the given command was not understood. The devices from Oxford Instruments reply with '?xxx' to a command 'xxx' if this command is not known, and replies with 'x' if the command is understood. If the command starts with an "$" the instrument will not reply at all; hence in that case there will be done no checking for a reply.

**Raises** `OxfordVISAError` if the instrument does not recognise the supplied command or if the response of the instrument is not understood

**class** pymeasure.instruments.oxfordinstruments.adapters.**OxfordVISAError**

Bases: `Exception`

### 7.27.2 Oxford Instruments Intelligent Temperature Controller 503

**class** pymeasure.instruments.oxfordinstruments.**ITC503**(*adapter*, *name='Oxford ITC503'*, *clear_buffer=True*, *min_temperature=0*, *max_temperature=1677.7*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Oxford Intelligent Temperature Controller 503.

```
itc = ITC503("GPIB::24")        # Default channel for the ITC503

itc.control_mode = "RU"         # Set the control mode to remote
itc.heater_gas_mode = "AUTO"    # Turn on auto heater and flow
itc.auto_pid = True             # Turn on auto-pid

print(itc.temperature_setpoint) # Print the current set-point
itc.temperature_setpoint = 300  # Change the set-point to 300 K
itc.wait_for_temperature()      # Wait for the temperature to stabilize
print(itc.temperature_1)        # Print the temperature at sensor 1
```

**class FLOW_CONTROL_STATUS**(*value*)

Bases: enum.IntFlag

IntFlag class for decoding the flow control status. Contains the following flags:

| bit | flag | meaning |
|---|---|---|
| 4 | HEATER_ERROR_SIGN | Sign of heater-error; True means negative |
| 3 | TEMPERATURE_ERROR_SIGN | Sign of temperature-error; True means negative |
| 2 | SLOW_VALVE_ACTION | Slow valve action occurring |
| 1 | COOLDOWN_TERMINATION | Cooldown-termination occurring |
| 0 | FAST_COOLDOWN | Fast-cooldown occurring |

**property auto_pid**

A boolean property that sets the Auto-PID mode on (True) or off (False).

**property auto_pid_table**

A property that controls values in the auto-pid table. Relies on *ITC503.x_pointer* and *ITC503.y_pointer* (or *ITC503.pointer*) to point at the location in the table that is to be set or read.

The x-pointer selects the table entry (1 to 16); the y-pointer selects the parameter:

| y-pointer | parameter |
|---|---|
| 1 | upper temperature limit |
| 2 | proportional band |
| 3 | integral action time |
| 4 | derivative action time |

**property control_mode**

A string property that sets the ITC in *local* or *remote* and *locked* or *unlocked*, locking the LOC/REM button. Allowed values are:

| value | state |
|---|---|
| LL | local & locked |
| RL | remote & locked |
| LU | local & unlocked |
| RU | remote & unlocked |

**property derivative_action_time**
A floating point property that controls the derivative action time for the PID controller in minutes. Can be set if the PID controller is in manual mode. Valid values are 0 [min.] to 273 [min.].

**property front_panel_display**
A string property that controls what value is displayed on the front panel of the ITC. Valid values are: 'temperature setpoint', 'temperature 1', 'temperature 2', 'temperature 3', 'temperature error', 'heater', 'heater voltage', 'gasflow', 'proportional band', 'integral action time', 'derivative action time', 'channel 1 freq/4', 'channel 2 freq/4', 'channel 3 freq/4'.

**property gasflow**
A floating point property that controls gas flow when in manual mode. The value is expressed as a percentage of the maximum gas flow. Valid values are in range 0 [off] to 99.9 [%].

**property gasflow_configuration_parameter**
A property that controls the gas flow configuration parameters. Relies on the `ITC503.x_pointer` to select which parameter is set or read:

| x-pointer | parameter |
|---|---|
| 1 | valve gearing |
| 2 | target table & features configuration |
| 3 | gas flow scaling |
| 4 | temperature error sensitivity |
| 5 | heater voltage error sensitivity |
| 6 | minimum gas valve in auto |

**property gasflow_control_status**
A property that reads the gas-flow control status. Returns the status in the form of a `ITC503.FLOW_CONTROL_STATUS` IntFlag.

**property heater**
A floating point property that represents the heater output power as a percentage of the maximum voltage. Can be set if the heater is in manual mode. Valid values are in range 0 [off] to 99.9 [%].

**property heater_gas_mode**
A string property that sets the heater and gas flow control to *auto* or *manual*. Allowed values are:

| value | state |
|---|---|
| MANUAL | heater & gas manual |
| AM | heater auto, gas manual |
| MA | heater manual, gas auto |
| AUTO | heater & gas auto |

**property heater_voltage**
A floating point property that represents the heater output power in volts. For controlling the heater, use the `ITC503.heater` property.

**property integral_action_time**
A floating point property that controls the integral action time for the PID controller in minutes. Can be set if the PID controller is in manual mode. Valid values are 0 [min.] to 140 [min.].

**property pointer**
A tuple property to set pointers into tables for loading and examining values in the table, of format (x, y). The significance and valid values for the pointer depends on what property is to be read or set. The value for x and y can be in the range 0 to 128.

**program_sweep**(*temperatures*, *sweep_time*, *hold_time*, *steps=None*)
Program a temperature sweep in the controller. Stops any running sweep. After programming the sweep, it can be started using OxfordITC503.sweep_status = 1.

**Parameters**

- **temperatures** – An array containing the temperatures for the sweep
- **sweep_time** – The time (or an array of times) to sweep to a set-point in minutes (between 0 and 1339.9).
- **hold_time** – The time (or an array of times) to hold at a set-point in minutes (between 0 and 1339.9).
- **steps** – The number of steps in the sweep, if given, the temperatures, sweep_time and hold_time will be interpolated into (approximately) equal segments

**property proportional_band**
A floating point property that controls the proportional band for the PID controller in Kelvin. Can be set if the PID controller is in manual mode. Valid values are 0 [K] to 1677.7 [K].

**property sweep_status**
An integer property that sets the sweep status. Values are:

| value | meaning |
|---|---|
| 0 | Sweep not running |
| 1 | Start sweep / sweeping to first set-point |
| 2P - 1 | Sweeping to set-point P |
| 2P | Holding at set-point P |

**property sweep_table**
A property that controls values in the sweep table. Relies on `ITC503.x_pointer` and `ITC503.y_pointer` (or `ITC503.pointer`) to point at the location in the table that is to be set or read.

The x-pointer selects the step of the sweep (1 to 16); the y-pointer selects the parameter:

| y-pointer | parameter |
|---|---|
| 1 | set-point temperature |
| 2 | sweep-time to set-point |
| 3 | hold-time at set-point |

**property target_voltage**
A float property that reads the current heater target voltage with which the actual heater voltage is being compared. Only valid if gas-flow in auto mode.

**property target_voltage_table**
A property that controls values in the target heater voltage table. Relies on the `ITC503.x_pointer` to select the entry in the table that is to be set or read (1 to 64).

**property temperature_1**
Reads the temperature of the sensor 1 in Kelvin.

**property temperature_2**
Reads the temperature of the sensor 2 in Kelvin.

**property temperature_3**
Reads the temperature of the sensor 3 in Kelvin.

**property temperature_error**
Reads the difference between the set-point and the measured temperature in Kelvin. Positive when set-point is larger than measured.

**property temperature_setpoint**
A floating point property that controls the temperature set-point of the ITC in kelvin. (dynamic)

**property valve_scaling**
A float property that reads the valve scaling parameter. Only valid if gas-flow in auto mode.

**property version**
A string property that returns the version of the IPS.

**wait_for_temperature**(*error=0.01*, *timeout=3600*, *check_interval=0.5*, *stability_interval=10*, *thermalize_interval=300*, *should_stop=<function ITC503.<lambda>>*)
Wait for the ITC to reach the set-point temperature.

**Parameters**

- **error** – The maximum error in Kelvin under which the temperature is considered at set-point
- **timeout** – The maximum time the waiting is allowed to take. If timeout is exceeded, a TimeoutError is raised. If timeout is None, no timeout will be used.
- **check_interval** – The time between temperature queries to the ITC.
- **stability_interval** – The time over which the temperature_error is to be below error to be considered stable.
- **thermalize_interval** – The time to wait after stabilizing for the system to thermalize.
- **should_stop** – Optional function (returning a bool) to allow the waiting to be stopped before its end.

**wipe_sweep_table**()
Wipe the currently programmed sweep table.

**property x_pointer**
An integer property to set pointers into tables for loading and examining values in the table. The significance and valid values for the pointer depends on what property is to be read or set.

**property y_pointer**
An integer property to set pointers into tables for loading and examining values in the table. The significance and valid values for the pointer depends on what property is to be read or set.

### 7.27.3 Oxford Instruments Intelligent Power Supply 120-10 for superconducting magnets

**class** pymeasure.instruments.oxfordinstruments.**IPS120_10**(*adapter*, *name='Oxford IPS'*, *clear_buffer=True*, *switch_heater_heating_delay=None*, *switch_heater_cooling_delay=None*, *field_range=None*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Oxford Superconducting Magnet Power Supply IPS 120-10.

```
ips = IPS120_10("GPIB::25")  # Default channel for the IPS

ips.enable_control()         # Enables the power supply and remote control

ips.train_magnet([           # Train the magnet after it has been cooled-down
    (11.8, 1.0),
    (13.9, 0.4),
    (14.9, 0.2),
    (16.0, 0.1),
])

ips.set_field(12)           # Bring the magnet to 12 T. The switch heater will
                            # be turned off when the field is reached and the
                            # current is ramped back to 0 (i.e. persistent mode).

print(self.field)           # Print the current field (whether in persistent or
                            # non-persistent mode)

ips.set_field(0)            # Bring the magnet to 0 T. The persistent mode will be
                            # turned off first (i.e. current back to set-point and
                            # switch-heater on); afterwards the switch-heater will
                            # again be turned off.

ips.disable_control()       # Disables the control of the supply, turns off the
                            # switch-heater and clamps the output.
```

**Parameters**

- **clear_buffer** – A boolean property that controls whether the instrument buffer is clear upon initialisation.
- **switch_heater_heating_delay** – The time in seconds (default is 20s) to wait after the switch-heater is turned on before the heater is expected to be heated.
- **switch_heater_cooling_delay** – The time in seconds (default is 20s) to wait after the switch-heater is turned off before the heater is expected to be cooled down.
- **field_range** – A numeric value or a tuple of two values to indicate the lowest and highest allowed magnetic fields. If a numeric value is provided the range is expected to be from `-field_range` to `+field_range`. The default range is -7 to +7 Tesla.

**property activity**

A string property that controls the activity of the IPS. Valid values are “hold”, “to setpoint”, “to zero” and “clamp”

**property control_mode**

A string property that sets the IPS in *local* or *remote* and *locked* or *unlocked*, locking the LOC/REM button. Allowed values are:

| value | state |
|---|---|
| LL | local & locked |
| RL | remote & locked |
| LU | local & unlocked |
| RU | remote & unlocked |

**property current_measured**

A floating point property that returns the measured magnet current of the IPS in amps. (dynamic)

**property current_setpoint**

A floating point property that controls the magnet current set-point of the IPS in ampere. (dynamic)

**property demand_current**

A floating point property that returns the demand magnet current of the IPS in amps. (dynamic)

**property demand_field**

A floating point property that returns the demand magnetic field of the IPS in Tesla. (dynamic)

**disable_control()**

Disable active control of the IPS (if at 0T) by turning off the switch heater, clamping the output and setting control to local. Raise a `MagnetError` if field not at 0T.

**disable_persistent_mode()**

Disable the persistent magnetic field mode. Raise a `MagnetError` if the magnet is not at rest.

**enable_control()**

Enable active control of the IPS by setting control to remote and turning off the clamp.

**enable_persistent_mode()**

Enable the persistent magnetic field mode. Raise a `MagnetError` if the magnet is not at rest.

**property field**

Property that returns the current magnetic field value in Tesla.

**property field_setpoint**

A floating point property that controls the magnetic field set-point of the IPS in Tesla. (dynamic)

**property persistent_field**

A floating point property that returns the persistent magnetic field of the IPS in Tesla. (dynamic)

**set_field**(*field*, *sweep_rate=None*, *persistent_mode_control=True*)

Change the applied magnetic field to a new specified magnitude. If allowed (via *persistent_mode_control*) the persistent mode will be turned off if needed and turned on when the magnetic field is reached. When the new field set-point is 0, the set-point of the instrument will not be changed but rather the *to zero* functionality will be used. Also, the persistent mode will not turned on upon reaching the 0T field in this case.

**Parameters**

- **field** – The new set-point for the magnetic field in Tesla.
- **sweep_rate** – A numeric value that controls the rate with which to change the magnetic field in Tesla/minute.
- **persistent_mode_control** – A boolean that controls whether the persistent mode may be turned off (if needed before sweeping) and on (when the field is reached); if

set to `False` but the system is in persistent mode, a *MagnetError* will be raised and the magnetic field will not be changed.

**property sweep_rate**
A floating point property that controls the sweep-rate of the IPS in Tesla/minute. (dynamic)

**property sweep_status**
A string property that returns the current sweeping mode of the IPS.

**property switch_heater_enabled**
A boolean property that controls whether the switch heater is enabled or not. When the switch heater is enabled (`True`), the switch is closed and the switch is open and the current in the magnet can be controlled; when the switch heater is disabled (`False`) the switch is closed and the current in the magnet cannot be controlled.

When turning on the switch heater with `True`, the switch heater is only activated if the current of the power supply matches the last recorded current in the magnet.

> **Warning:** These checks can be omitted by using `"Force"` in stead of `True`. Caution: Not performing these checks can cause serious damage to both the power supply and the magnet.

After turning on the switch heater it is necessary to wait several seconds for the switch the respond.

Raises a *SwitchHeaterError* if the system reports a 'heater fault' or if no switch is fitted on the system upon getting the status.

**property switch_heater_status**
An integer property that returns the switch heater status of the IPS. Use the *switch_heater_enabled* property for controlling and reading the switch heater. When using this property, the user is referred to the IPS120-10 manual for the meaning of the integer values.

**train_magnet**(*training_scheme*)
Train the magnet after cooling down. Afterwards, set the field back to 0 tesla (at last-used ramp-rate).

**Parameters** **training_scheme** – The training scheme as a list of tuples; each tuple should consist of a (field [T], ramp-rate [T/min]) pair.

**property version**
A string property that returns the version of the IPS.

**wait_for_idle**(*delay=1*, *max_wait_time=None*, *should_stop=<function IPS120_10.<lambda>>*)
Wait until the system is at rest (i.e. current of field not ramping).

**Parameters**

- **delay** – Time in seconds between each query into the state of the instrument.
- **max_wait_time** – Maximum time in seconds to wait before is at rest. If the system is not at rest within this time a `TimeoutError` is raised. `None` is interpreted as no maximum time.
- **should_stop** – A function that returns `True` when this function should return early.

**class** pymeasure.instruments.oxfordinstruments.ips120_10.**MagnetError**
Bases: `ValueError`

Exception that is raised for issues regarding the state of the magnet or power supply.

**class** pymeasure.instruments.oxfordinstruments.ips120_10.**SwitchHeaterError**
Bases: `ValueError`

Exception that is raised for issues regarding the state of the superconducting switch.

### 7.27.4 Oxford Instruments Power Supply 120-10 for superconducting magnets

**class** pymeasure.instruments.oxfordinstruments.**PS120_10**(*adapter*, *name='Oxford PS'*, ***kwargs*)

Bases: *pymeasure.instruments.oxfordinstruments.ips120_10.IPS120_10*

Represents the Oxford Superconducting Magnet Power Supply PS 120-10.

```
ps = PS120_10("GPIB::25")   # Default channel for the IPS

ps.enable_control()         # Enables the power supply and remote control

ps.train_magnet([           # Train the magnet after it has been cooled-down
    (11.8, 1.0),
    (13.9, 0.4),
    (14.9, 0.2),
    (16.0, 0.1),
])

ps.set_field(12)            # Bring the magnet to 12 T. The switch heater will
                            # be turned off when the field is reached and the
                            # current is ramped back to 0 (i.e. persistent mode).

print(self.field)           # Print the current field (whether in persistent or
                            # non-persistent mode)

ps.set_field(0)             # Bring the magnet to 0 T. The persistent mode will be
                            # turned off first (i.e. current back to set-point and
                            # switch-heater on); afterwards the switch-heater will
                            # again be turned off.

ps.disable_control()        # Disables the control of the supply, turns off the
                            # switch-heater and clamps the output.
```

**Parameters**

- **clear_buffer** – A boolean property that controls whether the instrument buffer is clear upon initialisation.
- **switch_heater_heating_delay** – The time in seconds (default is 20s) to wait after the switch-heater is turned on before the heater is expected to be heated.
- **switch_heater_cooling_delay** – The time in seconds (default is 20s) to wait after the switch-heater is turned off before the heater is expected to be cooled down.
- **field_range** – A numeric value or a tuple of two values to indicate the lowest and highest allowed magnetic fields. If a numeric value is provided the range is expected to be from `-field_range` to `+field_range`.

**class** pymeasure.instruments.oxfordinstruments.ips120_10.**MagnetError**

Bases: `ValueError`

Exception that is raised for issues regarding the state of the magnet or power supply.

**class** pymeasure.instruments.oxfordinstruments.ips120_10.**SwitchHeaterError**

Bases: `ValueError`

Exception that is raised for issues regarding the state of the superconducting switch.

## 7.28 Parker

This section contains specific documentation on the Parker instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.28.1 Parker GV6 Servo Motor Controller

**class** `pymeasure.instruments.parker.`**`ParkerGV6`**`(`*port*`)`

Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Parker Gemini GV6 Servo Motor Controller and provides a high-level interface for interacting with the instrument

**property angle**

Returns the angle in degrees based on the position and whether relative or absolute positioning is enabled, returning None on error

**property angle_error**

Returns the angle error in degrees based on the position error, or returns None on error

**disable**()

Disables the motor from moving

**echo**(*enable=False*)

Enables (True) or disables (False) the echoing of all commands that are sent to the instrument

**enable**()

Enables the motor to move

**is_moving**()

Returns True if the motor is currently moving

**kill**()

Stops the motor

**move**()

Initiates the motor to move to the setpoint

**property position**

Returns an integer number of counts that correspond to the angular position where 1 revolution equals 4000 counts

**property position_error**

Returns the error in the number of counts that corresponds to the error in the angular position where 1 revolution equals 4000 counts

**read**()

Overwrites the Instrument.read command to provide the correct functionality

**reset**()

Resets the motor controller while blocking and (CAUTION) resets the absolute position value of the motor

**set_defaults**()

Sets up the default values for the motor, which is run upon construction

**set_hardware_limits**(*positive=True*, *negative=True*)

Enables (True) or disables (False) the hardware limits for the motor

**set_software_limits**(*positive*, *negative*)

Sets the software limits for motion based on the count unit where 4000 counts is 1 revolution

**property status**
Returns a list of the motor status in readable format

**stop()**
Stops the motor during movement

**use_absolute_position()**
Sets the motor to accept setpoints from an absolute zero position

**use_relative_position()**
Sets the motor to accept setpoints that are relative to the last position

**write**(*command*)
Overwrites the Insturment.write command to provide the correct line break syntax

## 7.29 Pendulum

This section contains specific documentation on the Pendulum instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.29.1 Pendulum CNT91 frequency counter

**class** pymeasure.instruments.pendulum.cnt91.**CNT91**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents a Pendulum CNT-91 frequency counter.

**property batch_size**
Maximum number of buffer entries that can be transmitted at once.

**buffer_frequency_time_series**(*channel*, *n_samples*, *sample_rate*, *trigger_source=None*)
Record a time series to the buffer and read it out after completion.

**Parameters**

- **channel** – Channel that should be used
- **n_samples** – The number of samples
- **sample_rate** – Sample rate in Hz
- **trigger_source** – Optionally specify a trigger source to start the measurement

**configure_frequency_array_measurement**(*n_samples*, *channel*)
Configure the counter for an array of measurements.

**Parameters**

- **n_samples** – The number of samples
- **channel** – Measurment channel (A, B, C, E, INTREF)

**property continuous**
Controls whether to perform continuous measurements.

**property external_arming_start_slope**
Set slope for the start arming condition.

**property external_start_arming_source**
Select arming input or switch off the start arming function. Options are 'A', 'B' and 'E' (rear). 'IMM' turns trigger off.

**property format**
Reponse format (ASCII or REAL).

**property interpolator_autocalibrated**
Controls if interpolators should be calibrated automatically.

**property measurement_time**
Gate time for one measurement in s.

**read_buffer**(*expected_length=0*)
Read out the entire buffer.

**Parameters** **expected_length** – The expected length of the buffer. If more data is read, values at the end are removed. Defaults to 0, which means that the entire buffer is returned independent of its length.

**Returns** Frequency values from the buffer.

## 7.30 Razorbill

This section contains specific documentation on the Razorbill instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.30.1 Razorbill RP100 custrom power supply for Razorbill Instrums stress & strain cells

**class** pymeasure.instruments.razorbill.**razorbillRP100**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents Razorbill RP100 strain cell controller

```
scontrol = razorbillRP100("ASRL/dev/ttyACM0::INSTR")

scontrol.output_1 = True      # turns output on
scontrol.slew_rate_1 = 1      # sets slew rate to 1V/s
scontrol.voltage_1 = 10       # sets voltage on output 1 to 10V
```

**property contact_current_1**
Returns the current in amps present at the front panel output of channel 1

**property contact_current_2**
Returns the current in amps present at the front panel output of channel 2

**property contact_voltage_1**
Returns the Voltage in volts present at the front panel output of channel 1

**property contact_voltage_2**
Returns the Voltage in volts present at the front panel output of channel 2

**property instant_voltage_1**
Returns the instantaneous output of source one in volts

**property instant_voltage_2**
Returns the instanteneous output of source two in volts

**property output_1**
Turns output of channel 1 on or off

**property output_2**
Turns output of channel 2 on or off

**property slew_rate_1**
Sets or queries the source slew rate in volts/sec of channel 1

**property slew_rate_2**
Sets or queries the source slew rate in volts/sec of channel 2

**property voltage_1**
Sets or queries the output voltage of channel 1

**property voltage_2**
Sets or queries the output voltage of channel 2

## 7.31 Rohde & Schwarz

This section contains specific documentation on the Rohde & Schwarz instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.31.1 R&S SFM TV test transmitter

**class** pymeasure.instruments.rohdeschwarz.sfm.**SFM**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Rohde&Schwarz SFM TV test transmitter interface for interacting with the instrument.

**Note:** The current implementation only works with the first system in this unit.

Further source extension for system 2-6 would be required.

The intermodulation subsystem is also not yet implmented.

**property R75_out**
A bool property that controls the use of the 75R output (if installed)

| Value | Meaning |
|---|---|
| False | 50R output active (N) |
| True | 75R output active (BNC) |

refer also to chapter 3.6.5 of the manual

**property TV_country**
A string property that controls the country specifics of the video/sound system to be used

Possible values are:

| Value | Meaning |
|---|---|
| BG_G | BG General |
| DK_G | DK General |
| I_G | I General |
| L_G | L General |
| GERM | Germany |
| BELG | Belgium |
| NETH | Netherlands |
| FIN | Finland |
| AUST | Australia |
| BG_T | BG Th |
| DENM | Denmark |
| NORW | Norway |
| SWED | Sweden |
| GUS | Russia |
| POL1 | Poland |
| POL2 | Poland |
| HUNG | Hungary |
| CHEC | Czech Republic |
| CHINA1 | China |
| CHINA2 | China |
| GRE | Great Britain |
| SAFR | South Africa |
| FRAN | France |
| USA | United States |
| KOR | Korea |
| JAP | Japan |
| CAN | Canada |
| SAM | South America |

Please confirm with the manual about the details for these settings.

**property TV_standard**

A string property that controls the type of video standard

Possible values are:

| Value | Lines | System |
|---|---|---|
| BG | 625 | PAL |
| DK | 625 | SECAM |
| I | 625 | PAL |
| K1 | 625 | SECAM |
| L | 625 | SECAM |
| M | 525 | NTSC |
| N | 625 | NTSC |

Please confirm with the manual about the details for these settings.

**property basic_info**

A String property containing infomation about the hardware modules installed in the unit

**property beeper_enabled**

A bool property that controls the beeper status, refer also to chapter 3.6.8 of the manual

**calibration**(*number=1*, *subsystem=None*)

Function to either calibrate the whole modulator, when subsystem parameter is omitted, or calibrate a subsystem of the modulator.

Valid subsystem selections: "NICam, VISion, SOUNd1, SOUNd2, CODer"

**channel_down_relative**()

Decreases the output frequency to the next low channel/special channel based on the current country settings

**property channel_sweep_start**

A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property channel_sweep_step**

A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property channel_sweep_stop**

A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property channel_table**

A string property controlling which channel table is used

Possible selections are:

| Value | Meaning |
|---|---|
| DEF | Default channel table |
| USR1 | User table No. 1 |
| USR2 | User table No. 2 |
| USR3 | User table No. 3 |
| USR4 | User table No. 4 |
| USR5 | User table No. 5 |

refer also to chapter 3.6.6.1 of the manual

**channel_up_relative**()

Increases the output frequency to the next higher channel/special channel based on the current country settings

**coder_adjust**()

Starts the automatic setting of the differential deviation

refer also to chapter 3.6.6.4 of the manual

**property coder_id_frequency**

A int property that controls the frequency of the identification of the coder

valid range 0 .. 200 Hz

**property coder_modulation_degree**
A float property that controls the modulation degree of the identification of the coder

valid range: 0 .. 0.9

**property coder_pilot_deviation**
A int property that controls deviation of the pilot frequency of the coder

valid range: 1 .. 4 kHz

**property coder_pilot_frequency**
A int property that controls the pilot frequency of the coder

valid range: 40 .. 60 kHz

**property cw_frequency**
A float property controlling the CW-frequency in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property date**
A list property for the date of the RTC in the unit

**property event_reg**
Content of the event register of the Status Operation Register refer also to chapter 3.6.7 of the manual

**property ext_ref_base_unit**
A bool property for the external reference for the basic unit

| Value | Meaning |
|---|---|
| False | Internal 10 MHz is used |
| True | External 10 MHz is used |

**property ext_ref_extension**
A bool property for the external reference for the extension frame

| Value | Meaning |
|---|---|
| False | Internal 10 MHz is used |
| True | External 10 MHz is used |

**property ext_vid_connector**
A string property controlling which connector is used as the input of the video source

Possible selections are:

| Value | Meaning |
|---|---|
| HIGH | Front connector - Hi-Z |
| LOW | Front connector - 75R |
| REAR1 | Rear connector 1 |
| REAR2 | Rear connector 2 |
| AUTO | Automatic assignment |

**property external_modulation_frequency**
A int property that controls the setting for the external modulator frequency

valid range: 32 .. 46 MHz

**property external_modulation_power**
A int property that controls the setting for the external modulator output power

valid range: -7..0 dBm

refer also to chapter 3.6.6.5 of the manual

**property external_modulation_source**
A bool property for the modulation source selection

refer also to chapter 3.6.6.8 of the manual

**property frequency**
A float property controlling the frequency in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property frequency_mode**
A string property controlling which the unit is used in

Possible selections are:

| Value | Meaning |
|---|---|
| CW | Continous wave mode |
| FIXED | fixed frequency mode |
| CHSW | Channel sweep |
| RFSW | Frequency sweep |

**Note:** selecting the sweep mode, will start the sweep imemdiately!

**property gpib_address**
A int property that controls the GPIB address of the unit

valid range: 0..30

**property high_frequency_resolution**
A property that controls the frequency resolution,

Possible selections are:

| Value | Meaning |
|---|---|
| False | Low resolution (1000Hz) |
| True | High resolution (1Hz) |

**property level**
A float property controlling the output level in dBm,

- Minimum -99dBm
- Maximum 10dBm (depending on output mode)

refer also to chapter 3.6.6.2 of the manual

**property level_mode**
A string property controlling the output attenuator and linearity mode

Possible selections are:

| Value | Meaning | max. output level |
|---|---|---|
| NORM | Normal mode | +6 dBm |
| LOWN | low noise mode | +10 dBm |
| CONT | continous mode | +10 dBm |
| LOWD | low distortion mode | +0 dBm |

Contiuous mode allows up to 14 dB of level setting without use of the mechanical attenuator.

**property lower_sideband_enabled**
A bool property that controls the use of the lower sideband

refer also to chapter 3.6.6.10 of the manual

**property modulation_enabled**
A bool property that controls the modulation status

**property nicam_IQ_inverted**
A bool property that controls if the NICAM IQ signals are inverted or not

| Value | Meaning |
|---|---|
| False | normal (IQ) |
| True | inverted (QI) |

**property nicam_additional_bits**
A int property that controls the additional data in the NICAM modulator

valid range: 0 .. 2047

**property nicam_audio_frequency**
A int property that controls the frequency of the internal sound generator

valid range: 0 Hz .. 15 kHz

**property nicam_audio_volume**
A float property that controls the audio volume in the NICAM modulator in dB

valid range: 0..60 dB

**property nicam_bit_error_enabled**
A bool property that controls the status of an artifical bit error rate to be applied

**property nicam_bit_error_rate**
A float property that controls the artifical bit error rate.

valid range: 1.2E-7 .. 2E-3

**property nicam_carrier_enabled**
A bool property that controls if the NICAM carrier is switched on or off

**property nicam_carrier_frequency**
A float property that controls the frequency of the NICAM carrier

valid range: 33.05 MHz +/- 0.2 Mhz

**property nicam_carrier_level**
A float property that controls the value of the NICAM carrier

valid range: -40 .. -13 dB

**property nicam_control_bits**
A int property that controls the additional data in the NICAM modulator

valid range: 0 .. 3

**property nicam_data**
A int property that controls the data in the NICAM modulator

valid range: 0 .. 2047

**property nicam_intercarrier_frequency**
A float property that controls the inter-carrier frequency of the NICAM carrier

valid range: 5 .. 9 MHz

**property nicam_mode**
A string property that controls the signal type to be sent via NICAM

Possible values are:

| Value | Meaning |
|---|---|
| MON | Mono sound + NICAM data |
| STER | Stereo sound |
| DUAL | Dual channel sound |
| DATA | NICAM data only |

refer also to chapter 3.6.6.6 of the manual

**property nicam_preemphasis_enabled**
A bool property that controls the status of the J17 preemphasis

**property nicam_source**
A string property that controls the signal source for NICAM

Possible values are:

| Value | Meaning |
|---|---|
| INT | Internal audio generator(s) |
| EXT | External audio source |
| CW | Continous wave signal |
| RAND | Random data stream |
| TEST | Test signal |

**property nicam_test_signal**
A int property that controls the selection of the test signal applied

| Value | Meaning |
|---|---|
| 1 | Test signal 1 (91 kHz square wave, I&Q 90deg apart) |
| 2 | Test signal 2 (45.5 kHz square wave, I&Q 90deg apart) |
| 3 | Test signal 3 (182 kHz sine wave, I&Q in phase) |

**property normal_channel**
A int property controlling the current selected regular/normal channel number valid selections are based on the country settings.

**property operation_enable_reg**
Content of the enable register of the Status Operation Register

Valid range: 0…32767

**property output_voltage**
A float property controlling the output level in Volt,

Minimum 2.50891e-6, Maximum 0.707068 (depending on output mode) refer also to chapter 3.6.6.12 of the manual

**property questionable_event_reg**
Content of the event register of the Status Questionable Operation Register

**property questionable_operation_enable_reg**
Content of the enable register of the Status Questionable Operation Register

Valid range 0…32767

**property questionanble_status_reg**
Content of the condition register of the Status Questionable Operation Register

**property remote_interfaces**
A string property controlling the selection of interfaces for remote control

Possible selections are:

| Value | Meaning |
|---|---|
| OFF | no remote control |
| GPIB | GPIB only enabled |
| SER | RS232 only enabled |
| BOTH | GPIB & RS232 enabled |

**property rf_out_enabled**
A bool property that controls the status of the RF-output

**property rf_sweep_center**
A float property controlling the center frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property rf_sweep_span**
A float property controlling the sweep span in Hz,

- Minimum 1 kHz
- Maximum 1 GHz

**property rf_sweep_start**
A float property controlling the start frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property rf_sweep_step**
A float property controlling the stepwidth for sweep in Hz,

- Minimum 1 kHz
- Maximum 1 GHz

**property rf_sweep_stop**
A float property controlling the stop frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

**property scale_volt**

A string property that controls the unit to be used for voltage entries on the unit

Possible values are: AV,FV, PV, NV, UV, MV, V, KV, MAV, GV, TV, PEV, EV, DBAV, DBFV, DBPV, DBNV, DBUV, DBMV, DBV, DBKV, DBMAv, DBGV, DBTV, DBPEv, DBEV

refer also to chapter 3.6.9 of the manual

**property serial_baud**

A int property that controls the serial communication speed ,

Possible values are: 110,300,600,1200,4800,9600,19200

**property serial_bits**

A int property that controls the number of bits used in serial communication

Possible values are: 7 or 8

**property serial_flowcontrol**

A string property that controls the serial handshake type used in serial communication

Possible values are:

| Value | Meaning |
|---|---|
| NONE | no flow-control/handshake |
| XON | XON/XOFF flow-control |
| ACK | hardware handshake with RTS&CTS |

**property serial_parity**

A string property that controls the parity type used for serial communication

Possible values are:

| Value | Meaning |
|---|---|
| NONE | no parity |
| EVEN | even parity |
| ODD | odd parity |
| ONE | parity bit fixed to 1 |
| ZERO | parity bit fixed to 0 |

**property serial_stopbits**

A int property that controls the number of stop-bits used in serial communication,

Possible values are: 1 or 2

**property sound_mode**

A string property that controls the type of audio signal

Possible values are:

| Value | Meaning |
|---|---|
| MONO | MOnoaural sound |
| PIL | pilot-carrier + mono |
| BTSC | BTSC + mono |
| STER | Stereo sound |
| DUAL | Dual channel sound |
| NIC | NICAM + Mono |

**property special_channel**
A int property controlling the current selected special channel number valid selections are based on the country settings.

**property status_info_shown**
A bool property that controls if the display shows infomation during remote control

**status_preset()**
partly resets the SCPI status reporting structures

**property status_reg**
Content of the condition register of the Status Operation Register

**property subsystem_info**
A String property containing infomation about the system configuration

**property system_number**
A int property for the selected systems (if more than 1 available)

- Minimum 1
- Maximum 6

**property time**
A list property for the time of the RTC in the unit

**property vision_average_enabled**
A bool property that controls the average mode for the vision system

**property vision_balance**
A float property that controls the balance of the vision modulator

valid range: -0.5 .. 0.5

**property vision_carrier_enabled**
A bool property that controls the vision carrier status

refer also to chapter 3.6.6.9 of the manual

**property vision_carrier_frequency**
A float property that controls the frequency of the vision carrier

valid range: 32 .. 46 MHz

**property vision_clamping_average**
A float property that controls the operation point of the vision modulator

valid range: -0.5 .. 0.5

**property vision_clamping_enabled**
A bool property that controls the clamping behavior of the vision modulator

**property vision_clamping_mode**
A string property that controls the clamping mode of the vision modulator

Possible selections are HARD or SOFT

**property vision_precorrection_enabled**
A bool property that controls the precorrection behavior of the vision modulator

**property vision_residual_carrier_level**
A float property that controls the value of the residual carrier

valid range: 0 .. 0.3 (30%)

**property vision_sideband_filter_enabled**
A bool property that controls the use of the VSBF (vestigal sideband filter) in the vision modulator

**property vision_videosignal_enabled**
A bool property that controls if the video signal is switched on or off

**class** pymeasure.instruments.rohdeschwarz.sfm.**Sound_Channel**(*instrument*, *number*)
Bases: `object`

Class object for the two sound channels

refere also to chapter 3.6.6.7 of the user manual

**property carrier_enabled**
A bool property that controls if the audio carrier is switched on or off

**property carrier_frequency**
A float property that controls the frequency of the sound carrier

valid range: 32 .. 46 MHz

**property carrier_level**
A float property that controls the level of the audio carrier in dB relative to the vision carrier (0dB)

valid range: -34 .. -6 dB

**property deviation**
A int property that controls deviation of the selected audio signal

valid range: 0 .. 110 kHz

**property frequency**
A int property that controls the frequency of the internal sound generator

valid range: 300 Hz .. 15 kHz

**property modulation_degree**
A float property that controls the modulation depth for the audio signal (Note: only for the use of AM in Standard L)

valid range: 0 .. 1 (100%)

**property modulation_enabled**
A bool property that controls the audio modulation status

| Value | Meaning |
|---|---|
| False | modulation disabled |
| True | modulation enabled |

**property preemphasis_enabled**
A bool property that controls if the preemphasis for the audio is switched on or off

**property preemphasis_time**
A int property that controls if the mode of the preemphasis for the audio signal

| Value | Meaning |
|---|---|
| 50 | 50 us preemphasis |
| 75 | 75 us preemphasis |

**property use_external_source**
A bool property for the audio source selection

| Value | Meaning |
|---|---|
| False | Internal audio generator(s) |
| True | External signal source |

**values**(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any keyword arguments.

### 7.31.2 R&S FSL spectrum analyzer

#### Connecting to the instrument via network

Once connected to the network, the instrument's IP address can be found by clicking the "Setup" button and navigating to "General Settings" -> "Network Address".

It can then be connected like this:

```
from pymeasure.instruments.rohdeschwarz import FSL
fsl = FSL("TCPIP::192.168.1.123::INSTR")
```

#### Getting and setting parameters

Most parameters are implemented as properties, which means they can be read and written (getting and setting) in a consistent and simple way. If numerical values are provided, base units are used (s, Hz, dB, ...). Alternatively, the values can also be provided with a unit, e.g. `"1.5 GHz"` or `"1.5GHz"`. Return values are always numerical.

```
# Getting the current center frequency
fsl.freq_center

9000000000.0
```

```
# Changing it to 10 MHz by providing the numerical value
fsl.freq_center = 10e6
```

```
# Verifying:
fsl.freq_center

10000000.0
```

```
# Changing it to 9 GHz by providing a string and verifying the result
fsl.freq_center = '9GHz'
fsl.freq_center

9000000000.0
```

```
# Setting the span to maximum
fsl.freq_span = '7 GHz'
```

### Reading a trace

We will read the current trace

```
x, y = fsl.read_trace()
```

### Markers

Markers are implemented as their own class. You can create them like this:

```
m1 = fsl.create_marker()
```

Set peak exursion:

```
m1.peak_excursion = 3
```

Set marker to a specific position:

```
m1.x = 10e9
```

Find the next peak to the left and get the level:

```
m1.to_next_peak('left')
m1.y

-34.9349060059
```

### Delta markers

Delta markers can be created by setting the appropriate keyword.

```
d2 = fsl.create_marker(is_delta_marker=True)
d2.name

'DELT2'
```

### Example program

Here is an example of a simple script for recording the peak of a signal.

```
m1 = fsl.create_marker() # create marker 1

# Set standard settings, set to full span
fsl.continuous_sweep = False
fsl.freq_span = '18 GHz'
fsl.res_bandwidth = "AUTO"
fsl.video_bandwidth = "AUTO"
fsl.sweep_time = "AUTO"

# Perform a sweep on full span, set the marker to the peak and some to that marker
fsl.single_sweep()
m1.to_peak()
m1.zoom('20 MHz')

# take data from the zoomed-in region
fsl.single_sweep()
x, y = fsl.read_trace()
```

**class** pymeasure.instruments.rohdeschwarz.fsl.**FSL**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents a Rohde&Schwarz FSL spectrum analyzer.

All physical values that can be set can either be as a string of a value and a unit (e.g. "1.2 GHz") or as a float value in the base units (Hz, dBm, etc.).

**property attenuation**

Attenuation in dB.

**continue_single_sweep**()

Continue with single sweep with synchronization.

**property continuous_sweep**

Continuous (True) or single sweep (False)

**create_marker**(*num=1*, *is_delta_marker=False*)

Create a marker.

**Parameters**

- **num** – The marker number (1-4)
- **is_delta_marker** – True if the marker is a delta marker, default is False.

**Returns** The marker object.

**property freq_center**

Center frequency in Hz.

**property freq_span**

Frequency span in Hz.

**property freq_start**

Start frequency in Hz.

**property freq_stop**

Stop frequency in Hz.

**read_trace**(*n_trace=1*)
Read trace data.

**Parameters** **n_trace** – The trace number (1-6). Default is 1.

**Returns** 2d numpy array of the trace data, [[frequency], [amplitude]].

**property res_bandwidth**
Resolution bandwidth in Hz. Can be set to 'AUTO'

**single_sweep**()
Perform a single sweep with synchronization.

**property sweep_time**
Sweep time in s. Can be set to 'AUTO'.

**property trace_mode**
Trace mode ('WRIT', 'MAXH', 'MINH', 'AVER' or 'VIEW')

**property video_bandwidth**
Video bandwidth in Hz. Can be set to 'AUTO'

## 7.32 Signal Recovery

This section contains specific documentation on the Signal Recovery instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.32.1 DSP 7265 Lock-in Amplifier

**class** pymeasure.instruments.signalrecovery.**DSP7265**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

This is the class for the DSP 7265 lockin amplifier

**property adc1**
Reads the input value of ADC1 in Volts

**property adc2**
Reads the input value of ADC2 in Volts

**buffer_to_float**(*buffer_data*, *sensitivity=None*, *sensitivity2=None*, *raise_error=True*)
Method that converts fixed-point buffer data to floating point data.

The provided data is converted as much as possible, but there are some requirements to the data if all provided columns are to be converted; if a key in the provided data cannot be converted it will be omitted in the returned data or an exception will be raised, depending on the value of raise_error.

The requirements for converting the data are as follows:

- Converting X, Y, magnitude and noise requires sensitivity data, which can either be part of the provided data or can be provided via the sensitivity argument
- The same holds for X2, Y2 and magnitude2 with sensitivity2.
- Converting the frequency requires both 'frequency part 1' and 'frequency part 2'.

**Parameters**

- **buffer_data** (*dict*) – The data to be converted. Must be in the format as returned by the *get_buffer* method: a dict of numpy arrays.

- **sensitivity** – If provided, the sensitivity used to convert X, Y, magnitude and noise. Can be provided as a float or as an array that matches the length of elements in *buffer_data*. If both a sensitivity is provided and present in the buffer_data, the provided value is used for the conversion, but the sensitivity in the buffer_data is stored in the returned dict.
- **sensitivity2** – Same as the first sensitivity argument, but for X2, Y2, magnitude2 and noise2.
- **raise_error** (*bool*) – Determines whether an exception is raised in case not all keys provided in buffer_data can be converted. If False, the columns that cannot be converted are omitted in the returned dict.

**Returns** Floating-point buffer data

**Return type** dict

**property curve_buffer_bits**
An integer property that controls which data outputs are stored in the curve buffer. Valid values are values between 1 and 65,535 (or 2,097,151 in dual reference mode).

**property curve_buffer_interval**
An integer property that controls Sets the time interval between successive points being acquired in the curve buffer. The time interval is specified in ms with a resolution of 5 ms; input values are rounded up to a multiple of 5. Valid values are values between 0 and 1,000,000,000 (corresponding to 12 days). The interval may be set to 0, which sets the rate of data storage to the curve buffer to 1.25 ms/point (800 Hz). However this only allows storage of the X and Y channel outputs. There is no need to issue a CBD 3 command to set this up since it happens automatically when acquisition starts.

**property curve_buffer_length**
An integer property that controls the length of the curve buffer. Valid values are values between 1 and 32,768, but the actual maximum amount of points is determined by the amount of curves that are stored, as set via the curve_buffer_bits property (32,768 / n)

**property curve_buffer_status**
A property that represents the status of the curve buffer acquisition with four values: the first value represents the status with 5 possibilities (0: no activity, 1: acquisition via TD command running, 2: acquisition bya TDC command running, 5: acquisition via TD command halted, 6: acquisition bia TDC command halted); the second value is the number of sweeps that is acquired; the third value is the decimal representation of the status byte (the same response as the ST command; the fourth value is the number of points acquired in the curve buffer.

**property dac1**
A floating point property that represents the output value on DAC1 in Volts. This property can be set.

**property dac2**
A floating point property that represents the output value on DAC2 in Volts. This property can be set.

**property dac3**
A floating point property that represents the output value on DAC3 in Volts. This property can be set.

**property dac4**
A floating point property that represents the output value on DAC4 in Volts. This property can be set.

**property frequency**
A floating point property that represents the lock-in frequency in Hz. This property can be set.

**get_buffer**(*quantity=None*, *convert_to_float=True*, *wait_for_buffer=True*)
Method that retrieves the buffer after it has been filled. The data retrieved from the lock-in is in a fixed-point format, which requires translation before it can be interpreted as meaningful data. When *convert_to_float*

is True the conversion is performed (if possible) before returning the data.

**Parameters**

- **quantity** (*str*) – If provided, names the quantity that is to be retrieved from the curve buffer; can be any of: 'x', 'y', 'magnitude', 'phase', 'sensitivity', 'adc1', 'adc2', 'adc3', 'dac1', 'dac2', 'noise', 'ratio', 'log ratio', 'event', 'frequency part 1' and 'frequency part 2'; for both dual modes, additional options are: 'x2', 'y2', 'magnitude2', 'phase2', 'sensitivity2'. If no quantity is provided, all available data is retrieved.
- **convert_to_float** (*bool*) – Bool that determines whether to convert the fixed-point buffer-data to meaningful floating point values via the *buffer_to_float* method. If True, this method tries to convert all the available data to meaningful values; if this is not possible, an exception will be raised. If False, this conversion is not performed and the raw buffer-data is returned.
- **wait_for_buffer** (*bool*) – Bool that determines whether to wait for the data acquisition to finished if this method is called before the acquisition is finished. If True, the method waits until the buffer is filled before continuing; if False, the method raises an exception if the acquisition is not finished when the method is called.

`property harmonic`
An integer property that represents the reference harmonic mode control, taking values from 1 to 65535. This property can be set.

`property id`
Reads the instrument identification

`property imode`
Property that controls the voltage/current mode. can be 'voltage mode', 'current mode', or 'low noise current mode'

`init_curve_buffer()`
Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

`property log_ratio`
Reads the log ratio output, defined as log(X/ADC1)

`property mag`
Reads the magnitude in Volts

`property phase`
Reads the phase in degrees

`property ratio`
Reads the ratio output, defined as X/ADC1

`property reference`
Controls the oscillator reference. Can be "internal", "external rear" or "external front"

`property reference_phase`
A floating point property that represents the reference harmonic phase in degrees. This property can be set.

`property sensitivity`
A floating point property that controls the sensitivity range in Volts (for voltage mode) or Amps (for current modes). When in Volts it takes discrete values from 2 nV to 1 V. When in Amps it takes discrete values from 2 fA to 1 µA (for normal current mode) or up to 10 nA (for low noise current mode). This property can be set.

`setDifferentialMode`(*lineFiltering=True*)
Sets lockin to differential mode, measuring A-B

`set_buffer`(*points*, *quantities=None*, *interval=0.01*)
Method that prepares the curve buffer for a measurement.

**Parameters**

- **points** (*int*) – Number of points to be recorded in the curve buffer
- **quantities** (*list*) – List containing the quantities (strings) that are to be recorded in the curve buffer, can be any of: 'x', 'y', 'magnitude', 'phase', 'sensitivity', 'adc1', 'adc2', 'adc3', 'dac1', 'dac2', 'noise', 'ratio', 'log ratio', 'event', 'frequency' (or 'frequency part 1' and 'frequency part 2'); for both dual modes, additional options are: 'x2', 'y2', 'magnitude2', 'phase2', 'sensitivity2'. Default is 'x' and 'y'.
- **interval** (*float*) – The interval between two subsequent points stored in the curve buffer in s. Default is 10 ms.

`shutdown()`
Brings the instrument to a safe and stable state

**property slope**
A integer property that controls the filter slope in dB/octave, which can take the values 6, 12, 18, or 24 dB/octave. This property can be set.

`start_buffer()`
Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full.

**property time_constant**
A floating point property that controls the time constant in seconds, which takes values from 10 microseconds to 50,000 seconds. This property can be set.

**property voltage**
A floating point property that represents the voltage in Volts. This property can be set.

`wait_for_buffer`(*timeout=None*, *delay=0.1*)
Method that waits until the curve buffer is filled

**property x**
Reads the X value in Volts

**property xy**
Reads both the X and Y values in Volts

**property y**
Reads the Y value in Volts

## 7.33 Stanford Research Systems

This section contains specific documentation on the Stanford Research Systems (SRS) instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.33.1 SR510 Lock-in Amplifier

**class** pymeasure.instruments.srs.**SR510**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

**property frequency**

A float property representing the SR510 input reference frequency

**property output**

A float property that represents the SR510 output voltage in Volts.

**property phase**

A float property that represents the SR510 reference to input phase offset in degrees. Queries return values between -180 and 180 degrees. This property can be set with a range of values between -999 to 999 degrees. Set values are mapped internal in the lockin to -180 and 180 degrees.

**property sensitivity**

A float property that represents the SR510 sensitivity value. This property can be set.

**property status**

A string property representing the bits set within the SR510 status byte

**property time_constant**

A float property that represents the SR510 PRE filter time constant. This property can be set.

### 7.33.2 SR570 Lock-in Amplifier

**class** pymeasure.instruments.srs.**SR570**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

**property bias_enabled**

Boolean that turns the bias on or off. Allowed values are: True (bias on) and False (bias off)

**property bias_level**

A floating point value in V that sets the bias voltage level of the amplifier, in the [-5V,+5V] limits. The values are up to 1 mV precision level.

**blank_front**()

"Blanks the frontend output of the device

**clear_overload**()

"Reset the filter capacitors to clear an overload condition

**disable_bias**()

Turns the bias voltage off

**disable_offset_current**()

"Disables the offset current

**enable_bias**()

Turns the bias voltage on

**enable_offset_current**()

"Enables the offset current

**property filter_type**

A string that sets the filter type. Allowed values are: ['6dB Highpass', '12dB Highpass', '6dB Bandpass', '6dB Lowpass', '12dB Lowpass', 'none']

**property front_blanked**

Boolean that blanks(True) or un-blanks (False) the front panel

**property gain_mode**
A string that sets the gain mode. Allowed values are: ['Low Noise', 'High Bandwidth', 'Low Drift']

**property high_freq**
A floating point value that sets the highpass frequency of the amplifier, which takes a discrete value in a 1-3 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 0.03 Hz to 1 MHz.

**property invert_signal_sign**
An boolean sets the signal invert sense. Allowed values are: True (inverted) and False (not inverted).

**property low_freq**
A floating point value that sets the lowpass frequency of the amplifier, which takes a discrete value in a 1-3 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 0.03 Hz to 1 MHz.

**property offset_current**
A floating point value in A that sets the absolute value of the offset current of the amplifier, in the [1pA,5mA] limits. The offset current takes discrete values in a 1-2-5 sequence. Values are truncated to the closest allowed value if not exact.

**property offset_current_enabled**
Boolean that turns the offset current on or off. Allowed values are: True (current on) and False (current off).

**property offset_current_sign**
An string that sets the offset current sign. Allowed values are: 'positive' and 'negative'.

**property sensitivity**
A floating point value that sets the sensitivity of the amplifier, which takes discrete values in a 1-2-5 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 1 pA/V to 1 mA/V.

**property signal_inverted**
Boolean that inverts the signal if True

**unblank_front()**
Un-blanks the frontend output of the device

### 7.33.3 SR830 Lock-in Amplifier

**class pymeasure.instruments.srs.SR830**(*resourceName*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

**property adc1**
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

**property adc2**
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

**property adc3**
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

**property adc4**
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

**auto_offset**(*channel*)
Offsets the channel (X, Y, or R) to zero

**property aux_in_1**
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

**property aux_in_2**
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

**property aux_in_3**
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

**property aux_in_4**
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

**property aux_out_1**
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_2**
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_3**
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_4**
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property channel1**
A string property that represents the type of Channel 1, taking the values X, R, X Noise, Aux In 1, or Aux In 2. This property can be set.

**property channel2**
A string property that represents the type of Channel 2, taking the values Y, Theta, Y Noise, Aux In 3, or Aux In 4. This property can be set.

**property dac1**
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac2**
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac3**
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac4**
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property err_status**
Reads the value of the lockin error (ERR) status byte. Returns an IntFlag type with positions within the string corresponding to different error flags: bit 0: unused bit 1: backup error bit 2: RAM error bit 3: unused bit 4: ROM error bit 5: GPIB error bit 6: DSP error bit 7: Math error

**property filter_slope**
An integer property that controls the filter slope, which can take on the values 6, 12, 18, and 24 dB/octave. Values are truncated to the next highest level if they are not exact.

**property frequency**
A floating point property that represents the lock-in frequency in Hz. This property can be set.

**get_buffer**(*channel=1*, *start=0*, *end=None*)
Aquires the 32 bit floating point data through binary transfer

**get_scaling**(*channel*)
Returns the offset precent and the exapnsion term that are used to scale the channel in question

**property harmonic**
An integer property that controls the harmonic that is measured. Allowed values are 1 to 19999. Can be set.

**property input_config**
An string property that controls the input configuration. Allowed values are: ['A', 'A - B', 'I (1 MOhm)', 'I (100 MOhm)']

**property input_coupling**
An string property that controls the input coupling. Allowed values are: ['AC', 'DC']

**property input_grounding**
An string property that controls the input shield grounding. Allowed values are: ['Float', 'Ground']

**property input_notch_config**
An string property that controls the input line notch filter status. Allowed values are: ['None', 'Line', '2 x Line', 'Both']

**is_out_of_range**()
Returns True if the magnitude is out of range

**property lia_status**
Reads the value of the lockin amplifier (LIA) status byte. Returns a binary string with positions within the string corresponding to different status flags: bit 0: Input/Amplifier overload bit 1: Time constant filter overload bit 2: Output overload bit 3: Reference unlock bit 4: Detection frequency range switched bit 5: Time constant changed indirectly bit 6: Data storage triggered bit 7: unused

**property magnitude**
Reads the magnitude in Volts.

**output_conversion**(*channel*)
Returns a function that can be used to determine the signal from the channel output (X, Y, or R)

**property phase**
A floating point property that represents the lock-in phase in degrees. This property can be set.

**quick_range**()
While the magnitude is out of range, increase the sensitivity by one setting

**property reference_source**
An string property that controls the reference source. Allowed values are: ['External', 'Internal']

**property sample_frequency**
Gets the sample frequency in Hz

**property sensitivity**
A floating point property that controls the sensitivity in Volts, which can take discrete values from 2 nV to 1 V. Values are truncated to the next highest level if they are not exact.

**set_scaling**(*channel*, *precent*, *expand=0*)
Sets the offset of a channel (X=1, Y=2, R=3) to a certain precent (-105% to 105%) of the signal, with an optional expansion term (0, 10=1, 100=2)

**property sine_voltage**
A floating point property that represents the reference sine-wave voltage in Volts. This property can be set.

**snap**(*val1='X'*, *val2='Y'*, **vals*)
Method that records and retrieves 2 to 6 parameters at a single instant. The parameters can be one of: X, Y, R, Theta, Aux In 1, Aux In 2, Aux In 3, Aux In 4, Frequency, CH1, CH2. Default is "X" and "Y".

**Parameters**

- **val1** – first parameter to retrieve
- **val2** – second parameter to retrieve
- **vals** – other parameters to retrieve (optional)

**property theta**
Reads the theta value in degrees.

**property time_constant**
A floating point property that controls the time constant in seconds, which can take discrete values from 10 microseconds to 30,000 seconds. Values are truncated to the next highest level if they are not exact.

**wait_for_buffer**(*count*, *has_aborted=<function SR830.<lambda>>*, *timeout=60*, *timestep=0.01*)
Wait for the buffer to fill a certain count

**property x**
Reads the X value in Volts.

**property xy**
Reads the X and Y values in Volts.

**property y**
Reads the Y value in Volts.

### 7.33.4 SR860 Lock-in Amplifier

**class** pymeasure.instruments.srs.**SR860**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

**property adc1**
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

**property adc2**
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

**property adc3**
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

**property adc4**
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

**property aux_in_1**
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

**property aux_in_2**
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

**property aux_in_3**
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

**property aux_in_4**
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

**property aux_out_1**
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_2**
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_3**
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property aux_out_4**
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac1**
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac2**
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac3**
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dac4**
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

**property dcmode**
A string property that represents the sine out dc mode. This property can be set. Allowed values are:[‘COM’, ‘DIF’, ‘common’, ‘difference’]

**property detectedfrequency**
Returns the actual detected frequency in HZ.

**property extfreqency**
Returns the external frequency in Hz.

**property filer_synchronous**
A string property that represents the synchronous filter. This property can be set. Allowed values are:[‘Off’, ‘On’]

**property filter_advanced**
A string property that represents the advanced filter. This property can be set. Allowed values are:[‘Off’, ‘On’]

**property filter_slope**
A integer property that sets the filter slope to 6 dB/oct(i=0), 12 DB/oct(i=1), 18 dB/oct(i=2), 24 dB/oct(i=3).

**property frequency**
A floating point property that represents the lock-in frequency in Hz. This property can be set.

**property frequencypreset1**
A floating point property that represents the preset frequency for the F1 preset button. This property can be set.

**property frequencypreset2**
A floating point property that represents the preset frequency for the F2 preset button. This property can be set.

**property frequencypreset3**
A floating point property that represents the preset frequency for the F3 preset button. This property can be set.

**property frequencypreset4**
A floating point property that represents the preset frequency for the F4 preset button. This property can be set.

**property front_panel**
Turns the front panel blanking on(i=0) or off(i=1).

**property get_noise_bandwidth**
Returns the equivalent noise bandwidth, in hertz.

**property get_signal_strength_indicator**
Returns the signal strength indicator.

**property gettimebase**
Returns the current 10 MHz timebase source.

**property harmonic**
An integer property that controls the harmonic that is measured. Allowed values are 1 to 99. Can be set.

**property harmonicdual**
An integer property that controls the harmonic in dual reference mode that is measured. Allowed values are 1 to 99. Can be set.

**property horizontal_time_div**
A integer property for the horizontal time/div according to the following table:['0=0.5s', '1=1s', '2=2s', '3=5s', '4=10s', '5=30s', '6=1min', '7=2min', '8=5min', '9=10min', '10=30min', '11=1hour', '12=2hour', '13=6hour', '14=12hour', '15=1day', '16=2days']

**property input_coupling**
A string property that represents the input coupling. This property can be set. Allowed values are:['AC', 'DC']

**property input_current_gain**
A string property that represents the current input gain. This property can be set. Allowed values are:['1MEG', '100MEG']

**property input_range**
A string property that represents the input range. This property can be set. Allowed values are:['1V', '300M', '100M', '30M', '10M']

**property input_shields**
A string property that represents the input shield grounding. This property can be set. Allowed values are:['Float', 'Ground']

**property input_signal**
A string property that represents the signal input. This property can be set. Allowed values are:['VOLT', 'CURR', 'voltage', 'current']

**property input_voltage_mode**
A string property that represents the voltage input mode. This property can be set. Allowed values are:['A', 'A-B']

**property internalfrequency**
A floating property that represents the internal lock-in frequency in Hz This property can be set.

**property magnitude**
Reads the magnitude in Volts.

**property parameter_DAT1**
A integer property that assigns a parameter to data channel 1(green). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

**property parameter_DAT2**
A integer property that assigns a parameter to data channel 2(blue). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

**property parameter_DAT3**
A integer property that assigns a parameter to data channel 3(yellow). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

**property parameter_DAT4**
A integer property that assigns a parameter to data channel 3(orange). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

**property phase**
A floating point property that represents the lock-in phase in degrees. This property can be set.

**property reference_externalinput**
A string property that represents the external reference input. This property can be set. Allowed values are:['50OHMS', '1MEG']

**property reference_source**
A string property that represents the reference source. This property can be set. Allowed values are:['INT', 'EXT', 'DUAL', 'CHOP']

**property reference_triggermode**
A string property that represents the external reference trigger mode. This property can be set. Allowed values are:['SIN', 'POS', 'NEG', 'POSTTL', 'NEGTTL']

**property screen_layout**
A integer property that Sets the screen layout to trend(i=0), full strip chart history(i=1), half strip chart history(i=2), full FFT(i=3), half FFT(i=4) or big numerical(i=5).

**screenshot()**
Take screenshot on device The DCAP command saves a screenshot to a USB memory stick. This command is the same as pressing the [Screen Shot] key. A USB memory stick must be present in the front panel USB port.

**property sensitvity**
A floating point property that controls the sensitivity in Volts, which can take discrete values from 2 nV

to 1 V. Values are truncated to the next highest level if they are not exact.

**property sine_amplitudepreset1**
Floating point property representing the preset sine out amplitude, for the A1 preset button. This property can be set.

**property sine_amplitudepreset2**
Floating point property representing the preset sine out amplitude, for the A2 preset button. This property can be set.

**property sine_amplitudepreset3**
Floating point property representing the preset sine out amplitude, for the A3 preset button. This property can be set.

**property sine_amplitudepreset4**
Floating point property representing the preset sine out amplitude, for the A3 preset button. This property can be set.

**property sine_dclevelpreset1**
A floating point property that represents the preset sine out dc level for the L1 button. This property can be set.

**property sine_dclevelpreset2**
A floating point property that represents the preset sine out dc level for the L2 button. This property can be set.

**property sine_dclevelpreset3**
A floating point property that represents the preset sine out dc level for the L3 button. This property can be set.

**property sine_dclevelpreset4**
A floating point property that represents the preset sine out dc level for the L4 button. This property can be set.

**property sine_voltage**
A floating point property that represents the reference sine-wave voltage in Volts. This property can be set.

**snap**(*val1='X'*, *val2='Y'*, *val3=None*)
retrieve 2 or 3 parameters at once parameters can be chosen by index, or enumeration as follows:

j enumeration parameter j enumeration parameter

0 X X output 9 YNOise Ynoise 1 Y Youtput 10 OUT1 Aux Out1 2 R R output 11 OUT2 Aux Out2 3 THeta output 12 PHAse Reference Phase 4 IN1 Aux In1 13 SAMp Sine Out Amplitude 5 IN2 Aux In2 14 LEVel DC Level 6 IN3 Aux In3 15 FInt Int. Ref. Frequency 7 IN4 Aux In4 16 FExt Ext. Ref. Frequency 8 XNOise Xnoise

**Parameters**

- **val1** – parameter enumeration/index
- **val2** – parameter enumeration/index
- **val3** – parameter enumeration/index (optional)

**Defaults:** val1 = "X" val2 = "Y" val3 = None

**property strip_chart_dat1**
A integer property that turns the strip chart graph of data channel 1 off(i=0) or on(i=1).

**property strip_chart_dat2**
A integer property that turns the strip chart graph of data channel 2 off(i=0) or on(i=1).

**property strip_chart_dat3**
A integer property that turns the strip chart graph of data channel 1 off(i=0) or on(i=1).

**property strip_chart_dat4**
A integer property that turns the strip chart graph of data channel 4 off(i=0) or on(i=1).

**property theta**
Reads the theta value in degrees.

**property time_constant**
A floating point property that controls the time constant in seconds, which can take discrete values from 10 microseconds to 30,000 seconds. Values are truncated to the next highest level if they are not exact.

**property timebase**
Sets the external 10 MHZ timebase to auto(i=0) or internal(i=1).

**property x**
Reads the X value in Volts

**property y**
Reads the Y value in Volts

## 7.34 Tektronix

This section contains specific documentation on the Tektronix instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.34.1 TDS2000 Oscilloscope

**class** pymeasure.instruments.tektronix.**TDS2000**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Tektronix TDS 2000 Oscilloscope and provides a high-level for interacting with the instrument

### 7.34.2 AFG3152C Arbitrary function generator

**class** pymeasure.instruments.tektronix.**AFG3152C**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Tektronix AFG 3000 series (one or two channels) arbitrary function generator and provides a high-level for interacting with the instrument.

afg=AFG3152C("GPIB::1") # AFG on GPIB 1 afg.reset() # Reset to default afg.ch1.shape='sinusoidal' # Sinusoidal shape afg.ch1.unit='VPP' # Sets CH1 unit to VPP afg.ch1.amp_vpp=1 # Sets the CH1 level to 1 VPP afg.ch1.frequency=1e3 # Sets the CH1 frequency to 1KHz afg.ch1.enable() # Enables the output from CH1

## 7.35 Temptronic

This section contains specific documentation on the temptronic instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.35.1 Temptronic Base Class

**class** pymeasure.instruments.temptronic.**ATSBase**(*adapter*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

The base class for Temptronic ATSXXX instruments.

**property air_temperature**

Read air temperature in 0.1 °C increments.

**Type** float

**at_temperature**()

**Returns** `True` if at temperature.

**property auxiliary_condition_code**

Read out auxiliary condition status register.

**Type** int

Relevant flags are:

| Bit | Meaning |
|---|---|
| 10 | None |
| 9 | Ramp mode |
| 8 | Mode: 0 programming, 1 manual |
| 7 | None |
| 6 | TS status: 0 start-up, 1 ready |
| 5 | Flow: 0 off, 1 on |
| 4 | Sense mode: 0 air, 1 DUT |
| 3 | Compressor: 0 on, 1 off (heating possible) |
| 2 | Head: 0 lower, upper |
| 1 | None |
| 0 | None |

Refere to chapter 4 in the manual

**clear**()

Clear device-specific errors.

See `error_code` for further information.

**property compressor_enable**

`True` enables compressors, `False` disables it.

**Type** Boolean

**configure**(*temp_window=1*, *dut_type='T'*, *soak_time=30*, *dut_constant=100*, *temp_limit_air_low=- 60*, *temp_limit_air_high=220*, *temp_limit_air_dut=50*, *maximum_test_time=1000*)

Convenience method for most relevant configuration properties.

**Parameters**

- `dut_type` – string: indicating which DUT type to use
- `soak_time` – float: elapsed time in soak_window before settling is indicated
- `soak_window` – float: Soak window size or temperature settlings bounds (K)
- `dut_constant` – float: time constant of DUT, higher values indicate higher thermal mass
- `temp_limit_air_low` – float: minimum flow temperature limit (°C)
- `temp_limit_air_high` – float: maximum flow temperature limit (°C)
- `temp_limit_air_dut` – float: allowed temperature difference (K) between DUT and Flow
- `maximum_test_time` – float: maximum test time (seconds) for a single temperature point (safety)

**Returns** self

`property copy_active_setup_file`
Copy active setup file (0) to setup n (1 - 12).

**Type** int

`property current_cycle_count`
Read the number of cycles to do

**Type** int

`property cycling_enable`
CYCL Start/stop cycling.

**Type** bool

cycling_enable = True (start cycling) cycling_enable = False (stop cycling)

`cycling_stopped()`

**Returns** `True` if cycling has stopped.

`property dut_constant`
Control thermal constant (default 100) of DUT.

**Type** float

Lower values indicate lower thermal mass, higher values indicate higher thermal mass respectively.

`property dut_mode`
`On` enables DUT mode, `OFF` enables air mode

**Type** string

`property dut_temperature`
Read DUT temperature, in 0.1 °C increments.

**Type** float

`property dut_type`
Control DUT sensor type.

**Type** string

Possible values are:

| String | Meaning |
|---|---|
| ‘’ | no DUT |
| ‘T’ | T-DUT |
| ‘K’ | K-DUT |

Warning: If in DUT mode without DUT being connected, TS flags DUT error

**property dynamic_temperature_setpoint**
Read the dynamic temperature setpoint.

**Type** float

**property enable_air_flow**
Set TS air flow.

`True` enables air flow, `False` disables it

**Type** bool

**end_of_all_cycles()**

**Returns** `True` if cycling has stopped.

**end_of_one_cycle()**

**Returns** `True` if TS is at end of one cycle.

**end_of_test()**

**Returns** `True` if TS is at end of test.

**enter_cycle()**
Enter Cycle by sending `RMPC 1`.

**Returns** self

**enter_ramp()**
Enter Ramp by sending `RMPS 0`.

**Returns** self

**property error_code**
Read the device-specific error register (16 bits).

**Type** *ErrorCode*

**error_status()**
Returns error status code (maybe used for logging).

**Returns** *ErrorCode*

**property head**
Control TS head position.

**Type** string

`down`: transfer head to lower position `up`: transfer head to elevated position

**property learn_mode**
Control DUT automatic tuning (learning).

**Type** bool `False`: off `True`: automatic tuning on

**property load_setup_file**
loads setup file SFIL.

Valid range is between 1 to 12.

**Type** int

**property local_lockout**
`True` disables TS GUI, `False` enables it.

**property main_air_flow_rate**
Read main nozzle air flow rate in liters/sec.

**property maximum_test_time**
Control maximum allowed test time (s).

**Type** float

This prevents TS from staying at a single temperature forever. Valid range: 0 to 9999

**property mode**
Returns an integer indicating what the system is doing at the time the query is processed.

5: on Operator screen (manual mode) 6: on Cycle screen (program mode)

**next_setpoint()**
Step to the next setpoint during temperature cycling.

**not_at_temperature()**

**Returns** `True` if not at temperature.

**property nozzle_air_flow_rate**
Read main nozzle air flow rate in scfm.

**property ramp_rate**
Control ramp rate (K / min).

**Type** float

allowed values: nn.n: 0 to 99.9 in 0.1 K per minute steps. nnnn: 100 to 9999 in 1 K per minute steps.

**property remote_mode**
`True` disables TS GUI but displays a "Return to local" switch.

**reset()**
Reset (force) the System to the Operator screen.

**Returns** self

**property set_point_number**
Select a setpoint to be the current setpoint.

**Type** int

Valid range is 0 to 17 when on the Cycle screen or or 0 to 2 in case of operator screen (0=hot, 1=ambient, 2=cold).

**set_temperature**(*set_temp*)
sweep to a specified setpoint.

**Parameters** **set_temp** – target temperature for DUT (float)

**Returns** self

**shutdown**(*head=False*)
Turn down TS (flow and remote operation).

**Parameters** **head** – Lift head if `True`

**Returns** self

**start**(*enable_air_flow=True*)
start TS in remote mode.

**Parameters** **enable_air_flow** – flow starts if `True`

**Returns** self

**property temperature**
Read current temperature with 0.1 °C resolution.

**Type** float

Temperature readings origin depends on *dut_mode* setting. Reading higher than 400 (°C) indicates invalidity.

**property temperature_condition_status_code**
Temperature condition status register.

**Type** *TemperatureStatusCode*

**property temperature_event_status**
temperature event status register.

**Type** *TemperatureStatusCode*

Hint: Reading will clear register content.

**property temperature_limit_air_dut**
Air to DUT temperature limit.

**Type** float

Allowed difference between nozzle air and DUT temperature during settling. Valid range between 10 to 300 °C in 1 degree increments.

**property temperature_limit_air_high**
upper air temperature limit.

**Type** float

Valid range between 25 to 255 (°C). Setpoints above current value cause "out of range" error in TS.

**property temperature_limit_air_low**
Control lower air temperature limit.

**Type** float

Valid range between -99 to 25 (°C). Setpoints below current value cause "out of range" error in TS.

**property temperature_setpoint**
Set or get selected setpoint's temperature.

**Type** float

Valid range is -99.9 to 225.0 (°C) or as indicated by *temperature_limit_air_high* and *temperature_limit_air_low*. Use convenience function *set_temperature()* to prevent unexpected behavior.

**property temperature_setpoint_window**
Setpoint's temperature window.

**Type** float

Valid range is between 0.1 to 9.9 (°C). Temperature status register flags `at temperature` in case soak time elapsed while temperature stays in between bounds given by this value around the current setpoint.

**property temperature_soak_time**
Set the soak time for the currently selected setpoint.

**Type** float

Valid range is between 0 to 9999 (s). Lower values shorten cycle times. Higher values increase cycle times, but may reduce settling errors. See *temperature_setpoint_window* for further information.

**property total_cycle_count**
Set or read current cycle count (1 - 9999).

**Type** int

Sending 0 will stop cycling

**wait_for_settling**(*time_limit=300*)
block script execution until TS is settled.

**Parameters** **time_limit** – set the maximum blocking time within TS has to settle (float).

**Returns** self

Script execution is blocked until either TS has settled or time_limit has been exceeded (float).

**class** pymeasure.instruments.temptronic.temptronic_base.**TemperatureStatusCode**(*value*)
Temperature status enums based on `IntFlag`

Used in conjunction with *temperature_condition_status_code*.

| Value | Enum |
|---|---|
| 32 | CYCLING_STOPPED |
| 16 | END_OF_ALL_CYCLES |
| 8 | END_OF_ONE_CYCLE |
| 4 | END_OF_TEST |
| 2 | NOT_AT_TEMPERATURE |
| 1 | AT_TEMPERATURE |
| 0 | NO_STATUS |

**class** pymeasure.instruments.temptronic.temptronic_base.**ErrorCode**(*value*)
Error code enums based on `IntFlag`.

Used in conjunction with *error_code*.

| Value | Enum |
|---|---|
| 16384 | NO_DUT_SENSOR_SELECTED |
| 4096 | BVRAM_FAULT |
| 2048 | NVRAM_FAULT |
| 1024 | NO_LINE_SENSE |
| 512 | FLOW_SENSOR_HARDWARE_ERROR |
| 128 | INTERNAL_ERROR |
| 32 | AIR_SENSOR_OPEN |
| 16 | LOW_INPUT_AIR_PRESSURE |
| 8 | LOW_FLOW |
| 2 | AIR_OPEN_LOOP |
| 1 | OVERHEAT |
| 0 | OK |

### 7.35.2 Temptronic ATS525 Thermostream

**class** pymeasure.instruments.temptronic.**ATS525**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.temptronic.temptronic_base.ATSBase*

Represent the TemptronicATS525 instruments.

**property system_current**
Operating current.

**property temperature_limit_air_low**
Control lower air temperature limit.

**Type** float

Valid range between -60 to 25 (°C). Setpoints below current value cause "out of range" error in TS.

### 7.35.3 Temptronic ATS545 Thermostream

**class** pymeasure.instruments.temptronic.**ATS545**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.temptronic.temptronic_base.ATSBase*

Represents the TemptronicATS545 instrument.

Coding example

```
ts = ATS545('ASRL3::INSTR')  # replace adapter address
ts.configure()  # basic configuration (defaults to T-DUT)
ts.start()  # starts flow (head position not changed)
ts.set_temperature(25)  # sets temperature to 25 degC
ts.wait_for_settling()  # blocks script execution and polls for settling
ts.shutdown(head=False)  # disables thermostream, keeps head down
```

**property mode**
Returns an integer indicating what the system is doing at the time the query is processed. 10 = on Operator screen (manual mode) 0 = on Cycle screen (program mode) 63 = initial state after power-up

**next_setpoint**()
not implemented in ATS545

set `self.set_point_number` instead

**property temperature_limit_air_low**
Control lower air temperature limit.

**Type** float

Valid range between -80 to 25 (°C). Setpoints below current value cause "out of range" error in TS.

# 7.36 Thermotron

This section contains specific documentation on the Thermotron instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

## 7.36.1 Thermotron 3800 Oven

`pymeasure.instruments.thermotron.`**`thermotron3800`**
alias of <module 'pymeasure.instruments.thermotron.thermotron3800' from '/home/docs/checkouts/readthedocs.org/user_builds/pymeasure/checkouts/latest/pymeasure/instruments/thermotron/thermotron38

# 7.37 Thorlabs

This section contains specific documentation on the Thorlabs instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

## 7.37.1 Thorlabs PM100USB Powermeter

**class** `pymeasure.instruments.thorlabs.`**`ThorlabsPM100USB`**(*adapter*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents Thorlabs PM100USB powermeter.

**property energy**
Energy in J.

**property power**
Power in W.

**property wavelength**
Wavelength in nm.

**property wavelength_max**
Maximum wavelength, in nm

**property wavelength_min**
Minimum wavelength, in nm

### 7.37.2 Thorlabs Pro 8000 modular laser driver

**class** pymeasure.instruments.thorlabs.**ThorlabsPro8000**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents Thorlabs Pro 8000 modular laser driver

**property LDCCurrent**

Laser current.

**property LDCCurrentLimit**

Set Software current Limit (value must be lower than hardware current limit).

**property LDCPolarity**

Set laser diode polarity. Allowed values are: ['AG', 'CG']

**property LDCStatus**

Set laser diode status. Allowed values are: ['ON', 'OFF']

**property TEDSetTemperature**

Set TEC temperature

**property TEDStatus**

Set TEC status. Allowed values are: ['ON', 'OFF']

**property slot**

Slot selection. Allowed values are: range(1, 9)

## 7.38 Toptica

This section contains specific documentation on the Toptica Photonics instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.38.1 Toptica Adapters

**class** pymeasure.instruments.toptica.adapters.**TopticaAdapter**(*port*, *baud_rate*, ***kwargs*)

Bases: *pymeasure.adapters.visa.VISAAdapter*

Adapter class for connecting to Toptica Console via a serial connection.

**Parameters**

- **port** – pyvisa resource name of the instrument
- **baud_rate** – communication speed
- **kwargs** – Any valid key-word argument for VISAAdapter

**ask**(*command*)

Writes a command to the instrument and returns the resulting ASCII response

**Parameters command** – command string to be sent to the instrument

**Returns** String ASCII response of the instrument

**extract_value**(*reply*)

preprocess_reply function which tries to extract <value> from 'name = <value> [unit]'. If <value> can not be identified the orignal string is returned.

**Parameters reply** – reply string

**Returns** string with only the numerical value, or the original string

`read()`

Reads a reply of the instrument which consists of at least two lines. The initial ones are the reply to the command while the last one should be '[OK]' which acknowledges that the device is ready to receive more commands.

Note: '[OK]' is always returned as last message even in case of an invalid command, where a message indicating the error is returned before the '[OK]'

**Returns** string containing the ASCII response of the instrument.

`write`(*command*, *check_ack=True*)

Writes a command to the instrument. Also reads back a LF+CR which is always sent back.

**Parameters**

- `command` – command string to be sent to the instrument
- `check_ack` – flag to decide if also an acknowledgement from the device is expected. This is the case for set commands.

### 7.38.2 Toptica IBeam Smart Laser diode

`class pymeasure.instruments.toptica.ibeamsmart.IBeamSmart`(*port*, *baud_rate=115200*, ***kwargs*)

Bases: `pymeasure.instruments.instrument.Instrument`

IBeam Smart laser diode

**Parameters**

- `port` – pyvisa resource name of the instrument
- `baud_rate` – communication speed, defaults to 115200
- `kwargs` – Any valid key-word argument for VISAAdapter

`property channel1_enabled`

Status of Channel 1 of the laser. This can be True if the laser is on or False otherwise

`property channel2_enabled`

Status of Channel 2 of the laser. This can be True if the laser is on or False otherwise

`disable()`

shutdown all laser operation

`enable_continous()`

enable countinous emmission mode

`enable_pulsing()`

enable pulsing mode. The optical output is controlled by a digital input signal on a dedicated connnector on the device

`property laser_enabled`

Status of the laser diode driver. This can be True if the laser is on or False otherwise

`property power`

Actual output power in uW of the laser system. In pulse mode this means that the set value might not correspond to the readback one.

`property serial`

Serial number of the laser system

**property system_temp**
base plate (heatsink) temperature in degree centigrade.

**property temp**
temperature of the laser diode in degree centigrade.

**property version**
Firmware version number

## 7.39 Yokogawa

This section contains specific documentation on the Yokogawa instruments that are implemented. If you are interested in an instrument not included, please consider *adding the instrument*.

### 7.39.1 Yokogawa 7651 Programmable Supply

**class** pymeasure.instruments.yokogawa.**Yokogawa7651**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Yokogawa 7651 Programmable DC Source and provides a high-level for interacting with the instrument.

```
yoko = Yokogawa7651("GPIB::1")

yoko.apply_current()                # Sets up to source current
yoko.source_current_range = 10e-3   # Sets the current range to 10 mA
yoko.compliance_voltage = 10        # Sets the compliance voltage to 10 V
yoko.source_current = 0             # Sets the source current to 0 mA

yoko.enable_source()                # Enables the current output
yoko.ramp_to_current(5e-3)          # Ramps the current to 5 mA

yoko.shutdown()                     # Ramps the current to 0 mA and disables output
```

**apply_current**(*max_current=0.001*, *compliance_voltage=1*)
Configures the instrument to apply a source current, which can take optional parameters that defer to the *source_current_range* and *compliance_voltage* properties.

**apply_voltage**(*max_voltage=1*, *compliance_current=0.01*)
Configures the instrument to apply a source voltage, which can take optional parameters that defer to the *source_voltage_range* and *compliance_current* properties.

**property compliance_current**
A floating point property that sets the compliance current in Amps, which can take values from 5 to 120 mA.

**property compliance_voltage**
A floating point property that sets the compliance voltage in Volts, which can take values between 1 and 30 V.

**disable_source**()
Disables the source of current or voltage depending on the configuration of the instrument.

**enable_source**()
Enables the source of current or voltage depending on the configuration of the instrument.

**property id**
Returns the identification of the instrument

**ramp_to_current**(*current*, *steps=25*, *duration=0.5*)
Ramps the current to a value in Amps by traversing a linear spacing of current steps over a duration, defined in seconds.

**Parameters**

- **steps** – A number of linear steps to traverse
- **duration** – A time in seconds over which to ramp

**ramp_to_voltage**(*voltage*, *steps=25*, *duration=0.5*)
Ramps the voltage to a value in Volts by traversing a linear spacing of voltage steps over a duration, defined in seconds.

**Parameters**

- **steps** – A number of linear steps to traverse
- **duration** – A time in seconds over which to ramp

**shutdown**()
Shuts down the instrument, and ramps the current or voltage to zero before disabling the source.

**property source_current**
A floating point property that controls the source current in Amps, if that mode is active.

**property source_current_range**
A floating point property that sets the current voltage range in Amps, which can take values: 1 mA, 10 mA, and 100 mA. Currents are truncted to an appropriate value if needed.

**property source_enabled**
Reads a boolean value that is True if the source is enabled, determined by checking if the 5th bit of the OC flag is a binary 1.

**property source_mode**
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods `apply_current()` and `apply_voltage()` can also be used.

**property source_voltage**
A floating point property that controls the source voltage in Volts, if that mode is active.

**property source_voltage_range**
A floating point property that sets the source voltage range in Volts, which can take values: 10 mV, 100 mV, 1 V, 10 V, and 30 V. Voltages are truncted to an appropriate value if needed.

### 7.39.2 Yokogawa GS200 Source

**class** pymeasure.instruments.yokogawa.**YokogawaGS200**(*adapter*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Represents the Yokogawa GS200 source and provides a high-level interface for interacting with the instrument.

**property current_limit**
Floating point number that controls the current limit. "Limit" refers to maximum value of the electrical value that is conjugate to the mode (current is conjugate to voltage, and vice versa). Thus, current limit is only applicable when in 'voltage' mode

**property source_enabled**
A boolean property that controls whether the source is enabled, takes values True or False.

**property source_level**
Floating point number that controls the output level, either a voltage or a current, depending on the source mode.

**property source_mode**
String property that controls the source mode. Can be either 'current' or 'voltage'.

**property source_range**
Floating point number that controls the range (either in voltage or current) of the output. "Range" refers to the maximum source level.

**trigger_ramp_to_level**(*level*, *ramp_time*)
Ramp the output level from its current value to "level" in time "ramp_time". This method will NOT wait until the ramp is finished (thus, it will not block further code evaluation).

**Parameters**

- **level** (*float*) – final output level
- **ramp_time** (*float*) – time in seconds to ramp

**Returns** None

**property voltage_limit**
Floating point number that controls the voltage limit. "Limit" refers to maximum value of the electrical value that is conjugate to the mode (current is conjugate to voltage, and vice versa). Thus, voltage limit is only applicable when in 'current' mode

CHAPTER

EIGHT

# CONTRIBUTING

Contributions to the instrument repository and the main code base are highly encouraged. This section outlines the basic work-flow for new contributors.

## 8.1 Using the development version

New features are added to the development version of PyMeasure, hosted on GitHub. We use Git version control to track and manage changes to the source code. On Windows, we recommend using GitHub Desktop. Make sure you have an appropriate version of Git (or GitHub Desktop) installed and that you have a GitHub account.

In order to add your feature, you need to first fork PyMeasure. This will create a copy of the repository under your GitHub account.

The instructions below assume that you have set up Anaconda, as described in the *Quick Start guide* and describe the terminal commands necessary. If you are using GitHub Desktop, take a look through their documentation to understand the corresponding steps.

Clone your fork of PyMeasure `your-github-username/pymeasure`. In the following terminal commands replace your desired path and GitHub username.

```
cd /path/for/code
git clone https://github.com/your-github-username/pymeasure.git
```

If you had already installed PyMeasure using `pip`, make sure to uninstall it before continuing.

```
pip uninstall pymeasure
```

Install PyMeasure in the editable mode.

```
cd /path/for/code/pymeasure
pip install -e .
```

This will allow you to edit the files of PyMeasure and see the changes reflected. Make sure to reset your notebook kernel or Python console when doing so. Now you have your own copy of the development version of PyMeasure installed!

## 8.2 Working on a new feature

We use branches in Git to allow multiple features to be worked on simultaneously, without causing conflicts. The master branch contains the stable development version. Instead of working on the master branch, you will create your own branch off the master and merge it back into the master when you are finished.

Create a new branch for your feature before editing the code. For example, if you want to add the new instrument "Extreme 5000" you will make a new branch "dev/extreme-5000".

```
git branch dev/extreme-5000
```

You can also make a new branch on GitHub. If you do so, you will have to fetch these changes before the branch will show up on your local computer.

```
git fetch
```

Once you have created the branch, change your current branch to match the new one.

```
git checkout dev/extreme-5000
```

Now you are ready to write your new feature and make changes to the code. To ensure consistency, please follow the *coding standards for PyMeasure*. Use `git status` to check on the files that have been changed. As you go, commit your changes and push them to your fork.

```
git add file-that-changed.py
git commit -m "A short description about what changed"
git push
```

## 8.3 Making a pull-request

While you are working, its helpful to start a pull-request (PR) targeting the `master` branch of `pymeasure/pymeasure`. This will allow you to discuss your feature with other contributors. We encourage you to start this pull-request after your first commit.

Start a pull-request on the PyMeasure GitHub page.

There is some automation in place to run the unit tests and check some coding standards. Annotations in the "Files changed" tab indicate problems for you to correct (e.g. linting or docstring warnings).

Your pull-request will be reviewed by the PyMeasure maintainers. Frequently there is some iteration and discussion based on that feedback until a pull request can be merged. This will happen either in the conversation tab or in inline code comments.

Be aware that due to maintainer manpower limitations it might take a long time until PRs get reviewed and/or merged. In general, review effort scales badly with PR size. Therefore, smaller PRs are much preferred. Try to limit your contribution to one "aspect", e.g. one instrument (or a few if closely related), one bug fix, or one feature contribution.

If you placed your contribution in a separate branch as suggested above, you can easily use your contribution in the meantime – just check out your feature branch instead of *master*.

## 8.4 Unit testing

Unit tests are run each time a new commit is made to a branch. The purpose is to catch changes that break the current functionality, by testing each feature unit. PyMeasure relies on pytest to preform these tests, which are run on TravisCI and Appveyor for Linux/macOS and Windows respectively.

Running the unit tests while you develop is highly encouraged. This will ensure that you have a working contribution when you create a pull request.

```
pytest
```

If your feature can be tested, unit tests are required. This will ensure that your features keep working as new features are added.

Now you are familiar with all the pieces of the PyMeasure development work-flow. We look forward to seeing your pull-request!

# CHAPTER NINE

# REPORTING AN ERROR

Please report all errors to the Issues section of the PyMeasure GitHub repository. Use the search function to determine if there is an existing or resolved issued before posting.

CHAPTER

TEN

# ADDING INSTRUMENTS

You can make a significant contribution to PyMeasure by adding a new instrument to the `pymeasure.instruments` package. Even adding an instrument with a few features can help get the ball rolling, since its likely that others are interested in the same instrument.

Before getting started, become familiar with the *contributing work-flow* for PyMeasure, which steps through the process of adding a new feature (like an instrument) to the development version of the source code. This section will describe how to lay out your instrument code.

## 10.1 File structure

Your new instrument should be placed in the directory corresponding to the manufacturer of the instrument. For example, if you are going to add an “Extreme 5000” instrument you should add the following files assuming “Extreme” is the manufacturer. Use lowercase for all filenames to distinguish packages from CamelCase Python classes.

```
pymeasure/pymeasure/instruments/extreme/
    |--> __init__.py
    |--> extreme5000.py
```

### 10.1.1 Updating the init file

The `__init__.py` file in the manufacturer directory should import all of the instruments that correspond to the manufacturer, to allow the files to be easily imported. For a new manufacturer, the manufacturer should also be added to `pymeasure/pymeasure/instruments/__init__.py`.

### 10.1.2 Adding documentation

Documentation for each instrument is required, and helps others understand the features you have implemented. Add a new reStructuredText file to the documentation.

```
pymeasure/docs/api/instruments/extreme/
    |--> index.rst
    |--> extreme5000.rst
```

Copy an existing instrument documentation file, which will automatically generate the documentation for the instrument. The `index.rst` file should link to the `extreme5000` file. For a new manufacturer, the manufacturer should be also linked in `pymeasure/docs/api/instruments/index.rst`.

## 10.2 Instrument file

All standard instruments should be child class of *Instrument*. This provides the basic functionality for working with *Adapters*, which perform the actual communication.

The most basic instrument, for our "Extreme 5000" example starts like this:

```
#
# This file is part of the PyMeasure package.
#
# Copyright (c) 2013-2022 PyMeasure Developers
#
# Permission is hereby granted, free of charge, to any person obtaining a copy
# of this software and associated documentation files (the "Software"), to deal
# in the Software without restriction, including without limitation the rights
# to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
# copies of the Software, and to permit persons to whom the Software is
# furnished to do so, subject to the following conditions:
#
# The above copyright notice and this permission notice shall be included in
# all copies or substantial portions of the Software.
#
# THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
# IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
# FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
# AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
# LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
# OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
# THE SOFTWARE.
#

# from pymeasure.instruments import Instrument
```

This is a minimal instrument definition:

```
class Extreme5000(Instrument):
    """ Represents the imaginary Extreme 5000 instrument.
    """

    def __init__(self, resourceName, **kwargs):
        super().__init__(
            resourceName,
            "Extreme 5000",
            **kwargs
        )
```

Make sure to include the PyMeasure license to each file, and add yourself as an author to the `AUTHORS.txt` file.

In principle you are free to write any functions that are necessary for interacting with the instrument. When doing so, make sure to use the `self.ask(command)`, `self.write(command)`, and `self.read()` methods to issue command instead of calling the adapter directly.

In practice, we have developed a number of convenience functions for making instruments easy to write and maintain. The following sections detail these conveniences and are highly encouraged.

## 10.3 Defining default connection settings

When implementing instruments, it's sometimes necessary to define default connection settings. This might be because an instrument connection requires *specific non-default settings*, or because your instrument actually supports *multiple interfaces*.

The *VISAAdapter* class offers a flexible way of dealing with connection settings fully within the initializer of your instrument.

### 10.3.1 Single interface

The simplest version, suitable when the instrument connection needs default settings, just passes all keywords through to the `Instrument` initializer, which hands them over to *VISAAdapter* if `resourceName` is a string or integer.

```
def __init__(self, resourceName, **kwargs):
    super().__init__(
        resourceName,
        "Extreme 5000",
        **kwargs
    )
```

If you want to set defaults that should be prominently visible to the user and may be overridden, place them in the signature. This is suitable when the instrument has one type of interface, or any defaults are valid for all interface types, see the documentation in *VISAAdapter* for details.

```
def __init__(self, resourceName, baud_rate=2400, **kwargs):
    super().__init__(
        resourceName,
        "Extreme 5000",
        baud_rate=baud_rate,
        **kwargs
    )
```

If you want to set defaults, but they don't need to be prominently exposed for replacement, use this pattern, which sets the value only when there is no entry in `kwargs`, yet.

```
def __init__(self, resourceName, **kwargs):
    kwargs.setdefault('timeout', 1500)
    super().__init__(
        resourceName,
        "Extreme 5000",
        **kwargs
    )
```

### 10.3.2 Multiple interfaces

Now, if you have instruments with multiple interfaces (e.g. serial, TCPI/IP, USB), things get interesting. You might have settings common to all interfaces (like `timeout`), but also settings that are only valid for one interface type, but not others.

The trick is to add keyword arguments that name the interface type, like `asrl` or `gpib`, below (see here for the full list). These then contain a *dictionary* with the settings specific to the respective interface:

```
def __init__(self, resourceName, baud_rate=2400, **kwargs):
    kwargs.setdefault('timeout', 1500)
    super().__init__(
        resourceName,
        "Extreme 5000",
        gpib=dict(enable_repeat_addressing=False,
                  read_termination='\r'),
        asrl={'baud_rate': baud_rate,
              'read_termination': '\r\n'},
        **kwargs
    )
```

When the instrument instance is created, the interface-specific settings for the actual interface being used get merged with `**kwargs` before passing them on to PyVISA, the rest is discarded. This way, we always pass on a valid set of arguments. In addition, any entries in `**kwargs**` take precedence, so if they need to, it is *still* possible for users to override any defaults you set in the instrument definition.

For many instruments, the simple way presented first is enough, but in case you have a more complex arrangement to implement, pymeasure has your back!

### 10.3.3 Non-VISA Adapters

The approaches described above make use of the *VISAAdapter* and are recommended for use.

If, however, you are unable to use the *VISAAdapter* in your instrument, you can create your own *Adapter* instance internally:

```
def __init__(self, resourceName, baud_rate=2400, **kwargs):
    kwargs.setdefault('timeout', 0.5)
    kwargs.setdefault('xonxoff', True)
    adapter = SerialAdapter(resourceName,
                            baudrate=baud_rate,  # different arg name!
                            **kwargs)
    super().__init__(
        adapter,
        "Extreme 5000",
    )
```

Follow the user interface patterns presented above as closely as feasible (the code example shows how) so there is the least surprise for users used to other instruments. Please document well what kind of arguments may be passed into your instrument.

## 10.4 Writing properties

In PyMeasure, Python properties are the preferred method for dealing with variables that are read or set. PyMeasure comes with two convenience functions for making properties for classes. The `Instrument.measurement` function returns a property that issues a GPIB/SCPI requests when the value is used. For example, if our "Extreme 5000" has the `*IDN?` command we can write the following property to be added above the `def __init__` line in our above example class, or added to the class after the fact as in the code here:

```
Extreme5000.id = Instrument.measurement(
   "*IDN?", """ Reads the instrument identification """
)
```

You will notice that a documentation string is required, and should be descriptive and specific.

When we use this property we will get the identification information.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.id           # Reads "*IDN?"
'Extreme 5000 identification from instrument'
```

The `Instrument.control` function extends this behavior by creating a property that you can read and set. For example, if our "Extreme 5000" has the `:VOLT?` and `:VOLT <float>` commands that are in Volts, we can write the following property.

```
Extreme5000.voltage = Instrument.control(
    ":VOLT?", ":VOLT %g",
    """ A floating point property that controls the voltage
    in Volts. This property can be set.
    """
)
```

You will notice that we use the Python string format `%g` to pass through the floating point.

We can use this property to set the voltage to 100 mV, which will execute the command and then request the current voltage.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 0.1        # Executes ":VOLT 0.1"
>>> extreme.voltage              # Reads ":VOLT?"
0.1
```

Using `Instrument.control` and `Instrument.measurement` functions, you can create a number of properties for basic measurements and controls.

The `Instrument.control` function can be used with multiple values at once, passed as a tuple. Say, we may set voltages and frequencies in our "Extreme 5000", and the the commands for this are `:VOLTFREQ?` and `:VOLTFREQ <float>,<float>`, we could use the following property:

```
Extreme5000.combination = Instrument.control(
    ":VOLTFREQ?", ":VOLTFREQ %g,%g",
    """ A floating point property that simultaneously controls the voltage
    in Volts and the frequency in Hertz. This property can be set by a tuple.
    """
)
```

In use, we could set the voltage to 200 mV, and the Frequency to 931 Hz, and read both values immediately afterwards.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.combination = (0.2, 931)        # Executes ":VOLTFREQ 0.2,931"
>>> extreme.combination                     # Reads ":VOLTFREQ?"
[0.2, 931.0]
```

The next section details additional features of `Instrument.control` that allow you to write properties that cover specific ranges, or have to map between a real value to one used in the command. Furthermore it is shown how to perform more complex processing of return values from your device.

## 10.5 Advanced properties

Many GPIB/SCPI commands are more restrictive than our basic examples above. The `Instrument.control` function has the ability to encode these restrictions using `validators`. A validator is a function that takes a value and a set of values, and returns a valid value or raises an exception. There are a number of pre-defined validators in `pymeasure.instruments.validators` that should cover most situations. We will cover the four basic types here.

In the examples below we assume you have imported the validators.

In many situations you will also need to process the return string in order to extract the wanted quantity or process a value before sending it to the device. The `Instrument.control`, `Instrument.measurement` and `Instrument.setting` function also provide means to achieve this.

### 10.5.1 In a restricted range

If you have a property with a restricted range, you can use the `strict_range` and `truncated_range` functions.

For example, if our "Extreme 5000" can only support voltages from -1 V to 1 V, we can modify our previous example to use a strict validator over this range.

```
Extreme5000.voltage = Instrument.control(
    ":VOLT?", ":VOLT %g",
    """ A floating point property that controls the voltage
    in Volts, from -1 to 1 V. This property can be set. """,
    validator=strict_range,
    values=[-1, 1]
)
```

Now our voltage will raise a ValueError if the value is out of the range.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 100
Traceback (most recent call last):
...
ValueError: Value of 100 is not in range [-1,1]
```

This is useful if you want to alert the programmer that they are using an invalid value. However, sometimes it can be nicer to truncate the value to be within the range.

```
Extreme5000.voltage = Instrument.control(
    ":VOLT?", ":VOLT %g",
    """ A floating point property that controls the voltage
    in Volts, from -1 to 1 V. Invalid voltages are truncated.
```

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```
    This property can be set. """,
    validator=truncated_range,
    values=[-1, 1]
)
```

Now our voltage will not raise an error, and will truncate the value to the range bounds.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 100        # Executes ":VOLT 1"
>>> extreme.voltage
1.0
```

### 10.5.2 In a discrete set

Often a control property should only take a few discrete values. You can use the `strict_discrete_set` and `truncated_discrete_set` functions to handle these situations. The strict version raises an error if the value is not in the set, as in the range examples above.

For example, if our "Extreme 5000" has a `:RANG <float>` command that sets the voltage range that can take values of 10 mV, 100 mV, and 1 V in Volts, then we can write a control as follows.

```
Extreme5000.voltage = Instrument.control(
    ":RANG?", ":RANG %g",
    """ A floating point property that controls the voltage
    range in Volts. This property can be set.
    """,
    validator=truncated_discrete_set,
    values=[10e-3, 100e-3, 1]
)
```

Now we can set the voltage range, which will automatically truncate to an appropriate value.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 0.08
>>> extreme.voltage
0.1
```

### 10.5.3 Using maps

Now that you are familiar with the validators, you can additionally use maps to satisfy instruments which require non-physical values. The `map_values` argument of *Instrument.control* enables this feature.

If your set of values is a list, then the command will use the index of the list. For example, if our "Extreme 5000" instead has a `:RANG <integer>`, where 0, 1, and 2 correspond to 10 mV, 100 mV, and 1 V, then we can use the following control.

```
Extreme5000.voltage = Instrument.control(
    ":RANG?", ":RANG %d",
    """ A floating point property that controls the voltage
    range in Volts, which takes values of 10 mV, 100 mV and 1 V.
    This property can be set. """,
```

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```
    validator=truncated_discrete_set,
    values=[10e-3, 100e-3, 1],
    map_values=True
)
```

Now the actual GPIB/SCIP command is ":RANG 1" for a value of 100 mV, since the index of 100 mV in the values list is 1.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 100e-3
>>> extreme.read()
'1'
>>> extreme.voltage = 1
>>> extreme.voltage
1
```

Dictionaries provide a more flexible method for mapping between real-values and those required by the instrument. If instead the `:RANG <integer>` took 1, 2, and 3 to correspond to 10 mV, 100 mV, and 1 V, then we can replace our previous control with the following.

```
Extreme5000.voltage = Instrument.control(
    ":RANG?", ":RANG %d",
    """ A floating point property that controls the voltage
    range in Volts, which takes values of 10 mV, 100 mV and 1 V.
    This property can be set. """,
    validator=truncated_discrete_set,
    values={10e-3:1, 100e-3:2, 1:3},
    map_values=True
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 10e-3
>>> extreme.read()
'1'
>>> extreme.voltage = 100e-3
>>> extreme.voltage
0.1
```

The dictionary now maps the keys to specific values. The values and keys can be any type, so this can support properties that use strings:

```
Extreme5000.channel = Instrument.control(
    ":CHAN?", ":CHAN %d",
    """ A string property that controls the measurement channel,
    which can take the values X, Y, or Z.
    """,
    validator=strict_discrete_set,
    values={'X':1, 'Y':2, 'Z':3},
    map_values=True
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.channel = 'X'
>>> extreme.read()
'1'
>>> extreme.channel = 'Y'
>>> extreme.channel
'Y'
```

As you have seen, the `Instrument.control` function can be significantly extended by using validators and maps.

### 10.5.4 Processing of set values

The `Instrument.control`, and `Instrument.setting` allow a keyword argument *set_process* which must be a function that takes a value after validation and performs processing before value mapping. This function must return the processed value. This can be typically used for unit conversions as in the following example:

```
Extreme5000.current = Instrument.setting(
    ":CURR %g",
    """ A floating point property that takes the measurement current in A
    """,
    validator=strict_range,
    values=[0, 10],
    set_process=lambda v: 1e3*v,  # convert current to mA
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.current = 1  # set current to 1000 mA
```

### 10.5.5 Processing of return values

Similar to *set_process* the `Instrument.control`, and `Instrument.measurement` functions allow a *get_process* argument which if specified must be a function that takes a value and performs processing before value mapping. The function must return the processed value. In analogy to the example above this can be used for example for unit conversion:

```
Extreme5000.current = Instrument.control(
    ":CURR?", ":CURR %g",
    """ A floating point property representing the measurement current in A
    """,
    validator=strict_range,
    values=[0, 10],
    set_process=lambda v: 1e3*v,  # convert to mA
    get_process=lambda v: 1e-3*v,  # convert to A
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.current = 3.1
>>> extreme.current
3.1
```

*get_process* can also be used to perform string processing. Let's say your instrument returns a value with its unit which has to be removed. This could be achieved by the following code:

```
Extreme5000.capacity = Instrument.measurement(
    ":CAP?",
    """ A measurement returning a capacity in nF in the format '<cap> nF'
    """,
    get_process=lambda v: float(v.replace('nF', ''))
)
```

The same can be also achieved by the *preprocess_reply* keyword argument to `Instrument.control` or `Instrument.measurement`. This function is forwarded to `Adapter.values` and runs directly after receiving the reply from the device. One can therefore take advantage of the built in casting abilities and simplify the code accordingly:

```
Extreme5000.capacity = Instrument.measurement(
    ":CAP?",
    """ A measurement returning a capacity in nF in the format '<cap> nF'
    """,
    preprocess_reply=lambda v: v.replace('nF', '')
    # notice how we don't need to cast to float anymore
)
```

The real purpose of *preprocess_reply* is, however, for instruments where many/all properties need similar reply processing. *preprocess_reply* can be applied to all `Instrument.control` or `Instrument.measurement` properties, for example if all quantities are returned with a unit as in the example above. To avoid running into troubles for other properties this *preprocess_reply* should be clever enough to skip the processing in case it is not appropriate, for example if some identification string is returned. Typically this can be achieved by regular expression matching. In case of no match the reply is returned unchanged:

```
import re
_reg_value = re.compile(r"([-+]?[0-9]*\.?[0-9]+)\s+\w+")

def extract_value(reply):
    """ extract numerical value from reply. If none can be found the reply
    is returned unchanged.

    :param reply: reply string
    :returns: string with only the numerical value
    """
    r = _reg_value.search(reply)
    if r:
        return r.groups()[0]
    else:
        return reply

class Extreme5001(Instrument):
    """ Represents the imaginary Extreme 5001 instrument. This instrument
    sends numerical values including their units in an format "<value>
    <unit>".
    """
    capacity = Instrument.measurement(
        ":CAP?",
        """ A measurement returning a capacity in nF in the format '<cap> nF'
        """
```

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```
    )

    voltage = Instrument.measurement(
        ":VOLT?",
        """ A measurement returning a voltage in V in the format '<volt> V'
        """
    )

    id = Instrument.measurement(
        "*idn?",
        """ The identification of the instrument.
        """
    )

    def __init__(self, resourceName, **kwargs):
        super().__init__(
            resourceName,
            "Extreme 5000",
            preprocess_reply=extract_value,
            **kwargs,
        )
```

In cases where the general *preprocess_reply* function should not run it can be also overwritten in the property definition:

```
Extreme5001.channel = Instrument.control(
    ":CHAN?", ":CHAN %d",
    """ A string property that controls the measurement channel,
    which can take the values X, Y, or Z.
    """,
    validator=strict_discrete_set,
    values=[1,2,3],
    preprocess_reply=lambda v: v,
)
```

Using a combination of the decribed abilities also complex communication schemes can be achieved.

## 10.6 Dynamic properties

As described in previous sections, Python properties are a very powerful tool to easily code an instrument's programming interface. One very interesting feature provided in PyMeasure is the ability to adjust properties' behaviour in subclasses or dynamically in instances. This feature allows accomodating some interesting use cases with a very compact syntax.

Dynamic features of a property are enabled by setting its `dynamic` parameter to `True`.

Afterwards, creating specifically-named attributes (either in class definitions or on instances) allows modifying the parameters used at the time of property definition. You need to define an attribute whose name is *<property name>_<property_parameter>* and assign to it the desired value. Pay attention *not* to inadvertently define other class attribute or instance attribute names matching this pattern, since they could unintentionally modify the property behaviour.

**Note:** To clearly distinguish these special attributes from normal class/instance attributes, they can only be set, not read.

---

The mechanism works for all the parameters in properties, except `dynamic` and `docs` – see *Instrument.control*, *Instrument.measurement*, *Instrument.setting*.

Let us now consider a couple of common use cases for this functionality:

### 10.6.1 Dynamic validity range

Let's assume we have an instrument with a command that accepts a different valid range of values depending on its current state. The code below shows how this can be accomplished with dynamic properties.

```
Extreme5000.voltage = Instrument.control(
    ":VOLT?", ":VOLT %g",
    """ A floating point property that controls the voltage
    in Volts, from -1 to 1 V. This property can be set. """,
    validator=strict_range,
    values=[-1, 1],
    dynamic = True,
)
def set_bipolar_mode(self, enabled = True):
    """Safely switch between bipolar/unipolar mode."""

    # some code to switch off the output first
    # ...

    if enabled:
        self.mode = "BIPOLAR"
        # set valid range of "voltage" property
        self.voltage_values = [-1, 1]
    else:
        self.mode = "UNIPOLAR"
        # note the "propertyname_parametername" form of the attribute
        self.voltage_values = [0, 1]
```

Now our voltage property has a dynamic validity range, either [-1, 1] or [0, 1]. In this example, the property name was `voltage` and the parameter to adjust was `values`, so we used `self.voltage_values` to set our desired values.

### 10.6.2 Family of instruments with similar features

A common case is to have a family of similar instruments with some parameter range different for each family member. In this case you would update the specific class parameter range without rewriting the entire property:

```
class FictionalInstrumentFamily(Instrument):
    frequency = Instrument.setting(
        "FREQ %g",
        """ Command docstring""",
        validator=strict_range,
        values=[0, 1e9],
        # ... other possible parameters follow
    )
    #
```

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```
    # ... complete class implementation here
    #

class FictionalInstrument_1GHz(FictionalInstrumentFamily):
    pass

class FictionalInstrument_3GHz(FictionalInstrumentFamily):
    frequency_values = [0, 3e9]

class FictionalInstrument_9GHz(FictionalInstrumentFamily):
    frequency_values = [0, 9e9]
```

Notice how easily you can derive the different family members from a common class, and the fact that the attribute is now defined at class level and not at instance level.

### 10.6.3 Compatibility of instruments with similar features

Another use case involves maintaining compatibility between instruments with commands having different syntax.

```
class MultimeterA(Instrument):
    voltage = Instrument.measurement(get_command="VOLT?",...)

    # ...full class definition code here

class MultimeterB(MultimeterA):
    # Same as brand A multimeter, but the command to read voltage
    # is slightly different
    voltage_get_command = "VOLTAGE?"
```

In the above example, `MultimeterA` and `MultimeterB` use a different command to read the voltage, but the rest of the behaviour is identical. `MultimeterB` can be defined subclassing `MultimeterA` and just implementing the difference.

CHAPTER

ELEVEN

# CODING STANDARDS

In order to maintain consistency across the different instruments in the PyMeasure repository, we enforce the following standards.

## 11.1 Python style guides

The PEP8 style guide and PEP257 docstring conventions should be followed.

Function and variable names should be lower case with underscores as needed to seperate words. CamelCase should only be used for class names, unless working with Qt, where its use is common.

In addition, there is a configuration for the flake8 linter present. Our codebase should not trigger any warnings. Many editors/IDEs can run this tool in the background while you work, showing results inline. Alternatively, you can run `flake8` in the repository root to check for problems. In addition, our automation on Github also runs some checkers. As this results in a much slower feedback loop for you, it's not recommended to rely only on this.

There are no plans to support type hinting in PyMeasure code. This adds a lot of additional code to manage, without a clear advantage for this project. Type documentation should be placed in the docstring where not clear from the variable name.

## 11.2 Documentation

PyMeasure documents code using reStructuredText and the Sphinx documentation generator. All functions, classes, and methods should be documented in the code using a docstring.

## 11.3 Usage of getter and setter functions

Getter and setter functions are discouraged, since properties provide a more fluid experience. Given the extensive tools avalible for defining properties, detailed in the *Advanced properties* section, these types of properties are prefered.

CHAPTER

# TWELVE

# AUTHORS

PyMeasure was started in 2013 by Colin Jermain and Graham Rowlands at Cornell University, when it became apparent that both were working on similar Python packages for scientific measurements. PyMeasure combined these efforts and continues to gain valuable contributions from other scientists who are interested in advancing measurement software.

The following developers have contributed to the PyMeasure package:

Colin Jermain
Graham Rowlands
Minh-Hai Nguyen
Guen Prawiro-Atmodjo
Tim van Boxtel
Davide Spirito
Marcos Guimaraes
Ghislain Antony Vaillant
Ben Feinstein
Neal Reynolds
Christoph Buchner
Julian Dlugosch
Sylvain Karlen
Joseph Mittelstaedt
Troy Fox
Vikram Sekar
Casper Schippers
Sumatran Tiger
Michael Schneider
Dennis Feng
Stefano Pirotta
Moritz Jung
Richard Schlitz
Manuel Zahn
Mikhaël Myara
Domenic Prete
Mathieu Jeannin
Paul Goulain
John McMaster
Dominik Kriegner

Jonathan Larochelle
Dominic Caron
Mathieu Plante
Michele Sardo
Steven Siegl
Benjamin Klebel-Knobloch
Demetra Adrahtas
Dan McDonald
Hud Wahab
Nicola Corna
Robert Eckelmann
Sam Condon
Andreas Maeder
Bastian Leykauf
Matthew Delaney
Marco von Rosenberg
Jack Van Sambeek
JC Arbelbide

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