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 1

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:

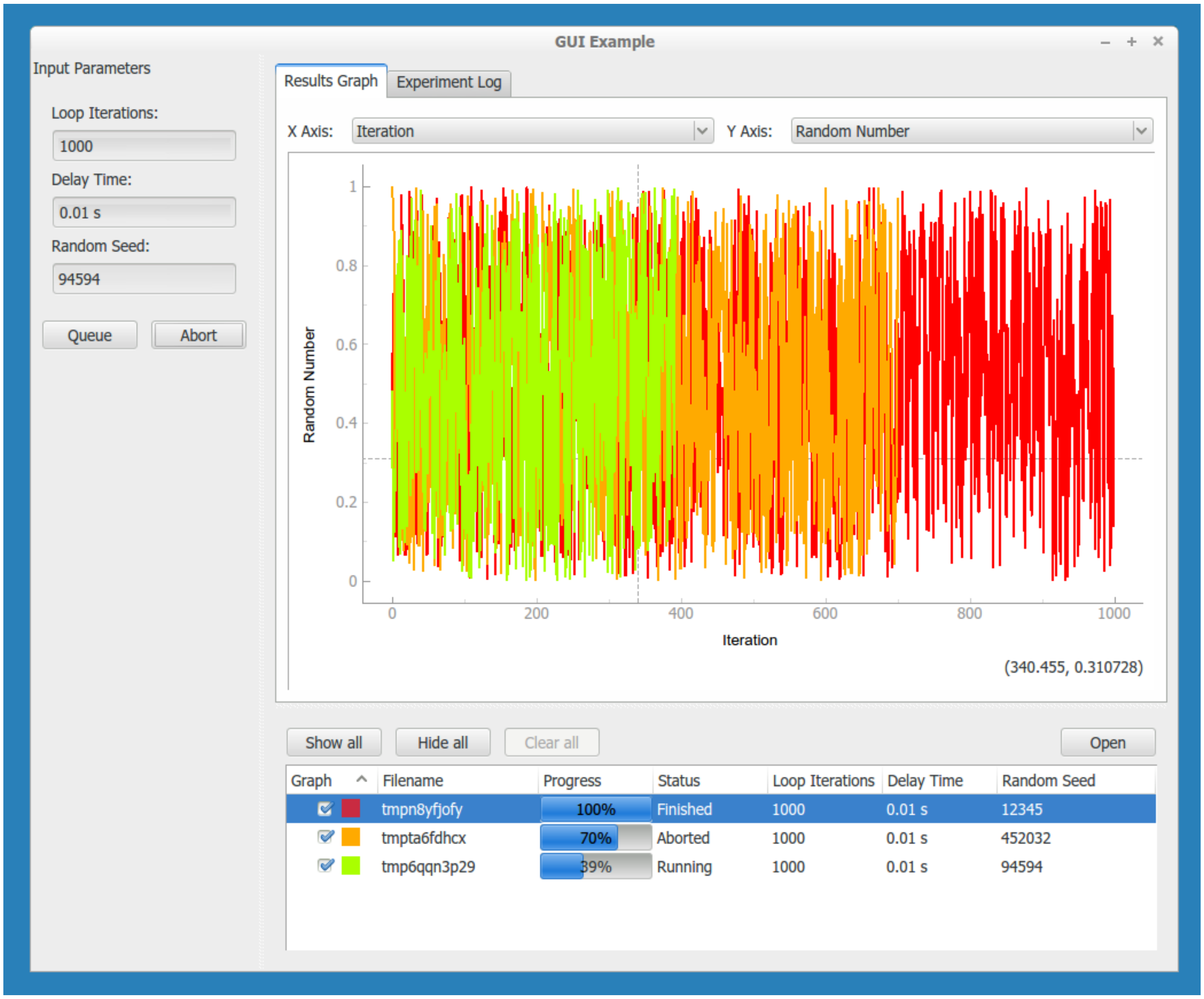
```
from pymeasure.instruments.keithley import Keithley2400
```

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 2

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 3.5 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 3

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.

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 *ProlgixAdapter*), 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")
```

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
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()
```

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```
    # 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
```

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```
        """
        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

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):

    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
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)
```

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```
            if self.should_stop():
                log.info("User aborted the procedure")
                break

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

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.

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.

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

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```
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)
            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()
    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")
```

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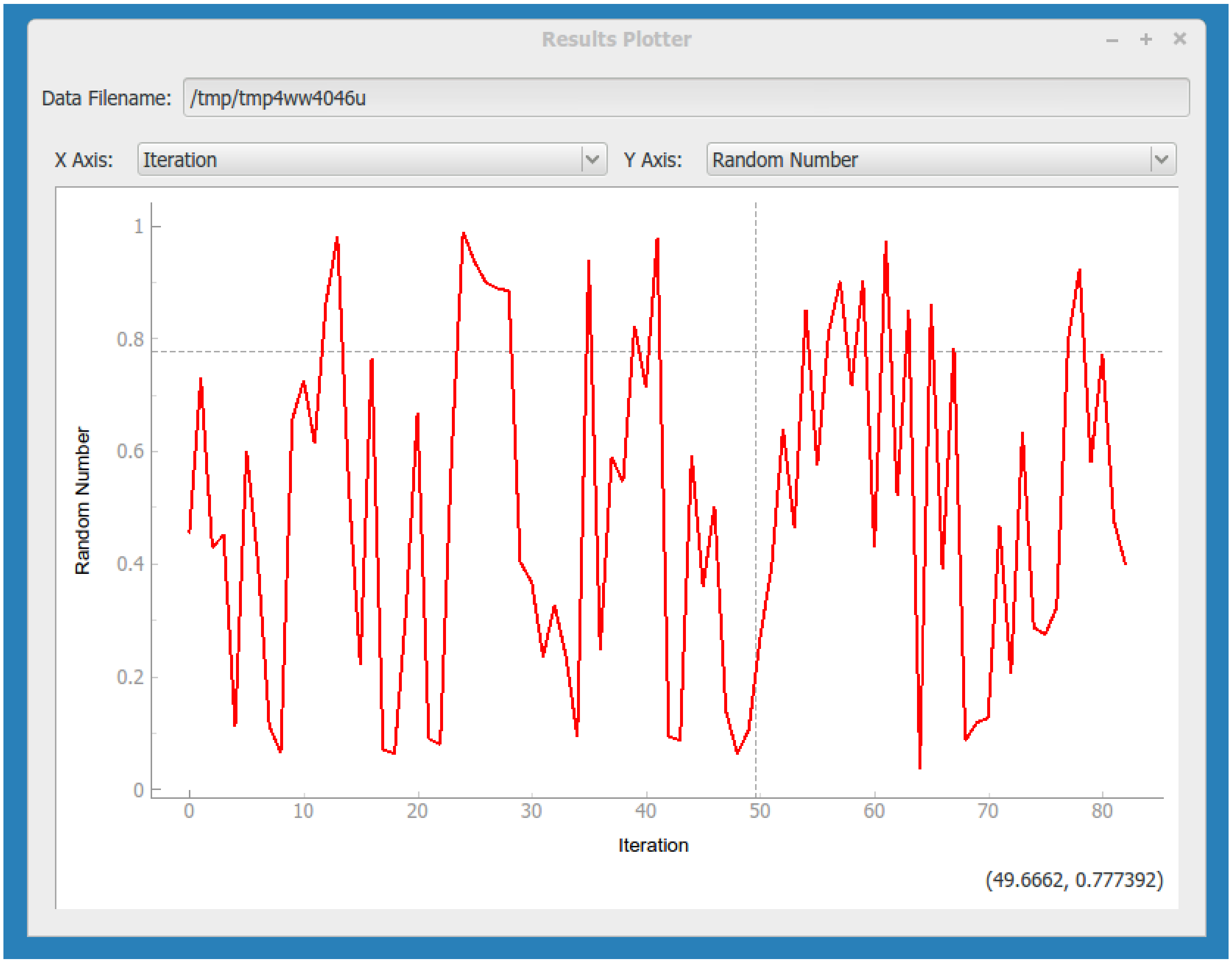
```
    worker.join(timeout=3600) # wait at most 1 hr (3600 sec)
    log.info("Finished the measurement")
```

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)
            sleep(self.delay)
            if self.should_stop():
                log.warning("Caught the stop flag in the procedure")
                break


class MainWindow(ManagedWindow):

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

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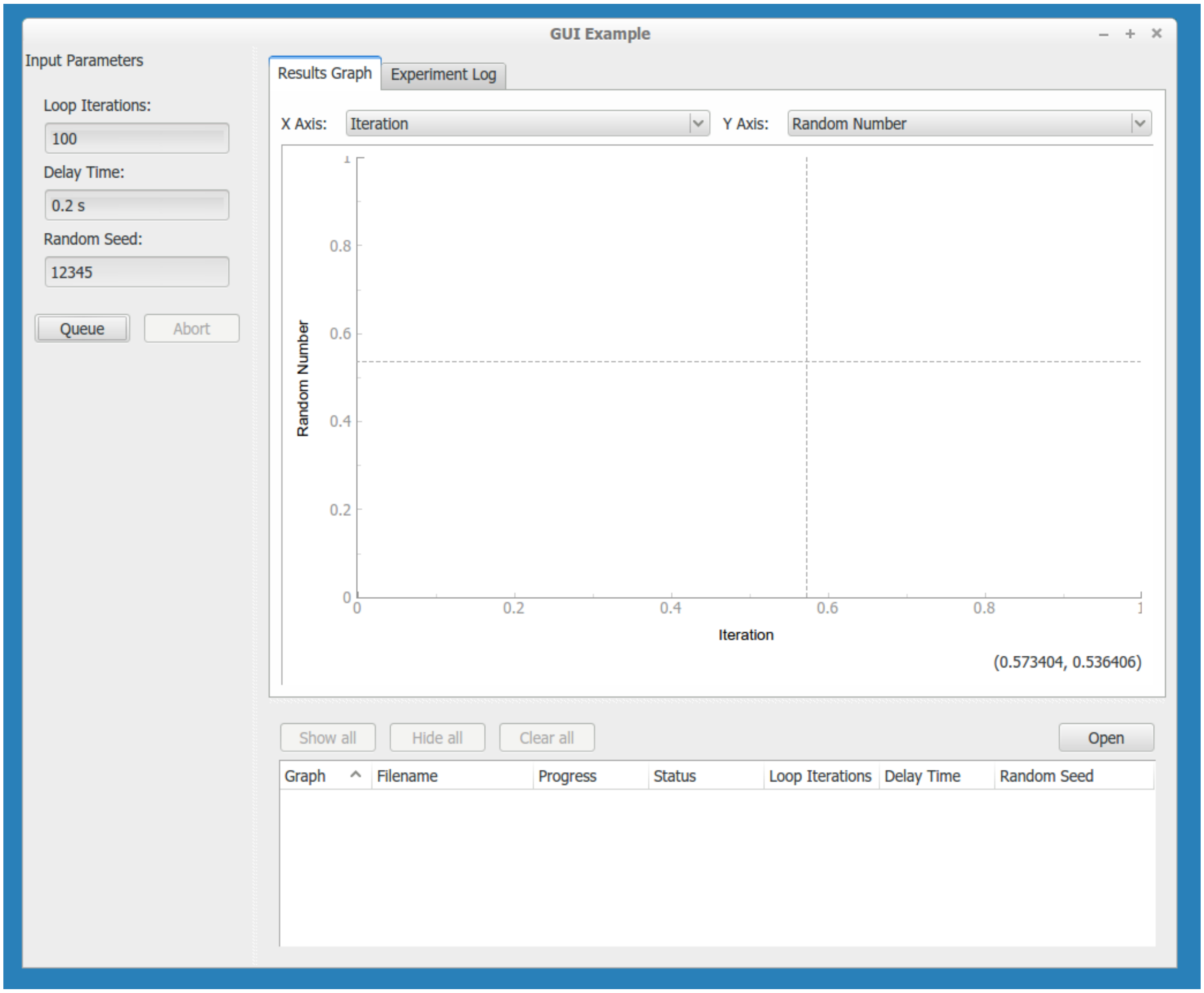
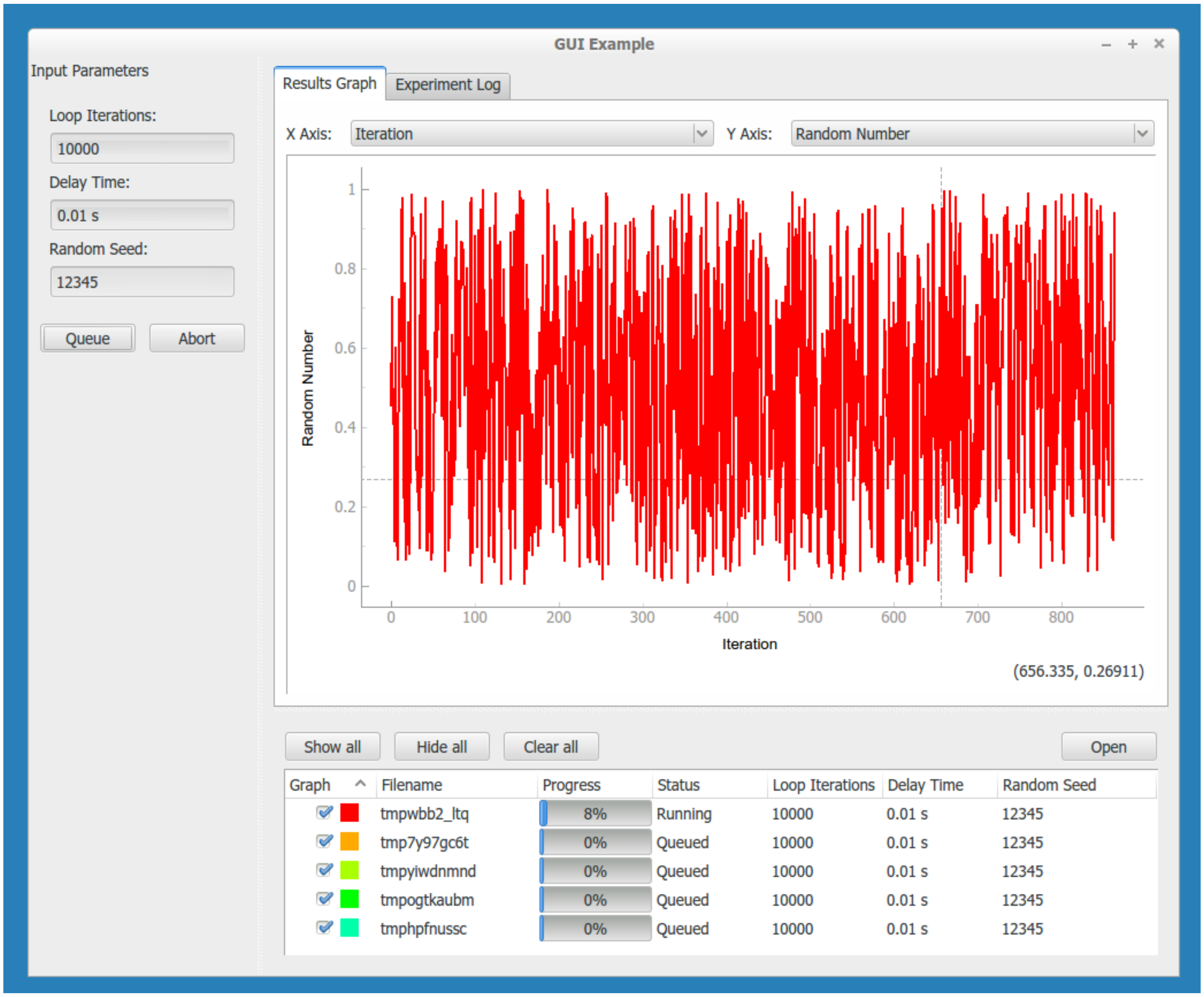
```
    def queue(self):
        filename = tempfile.mktemp()

        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.

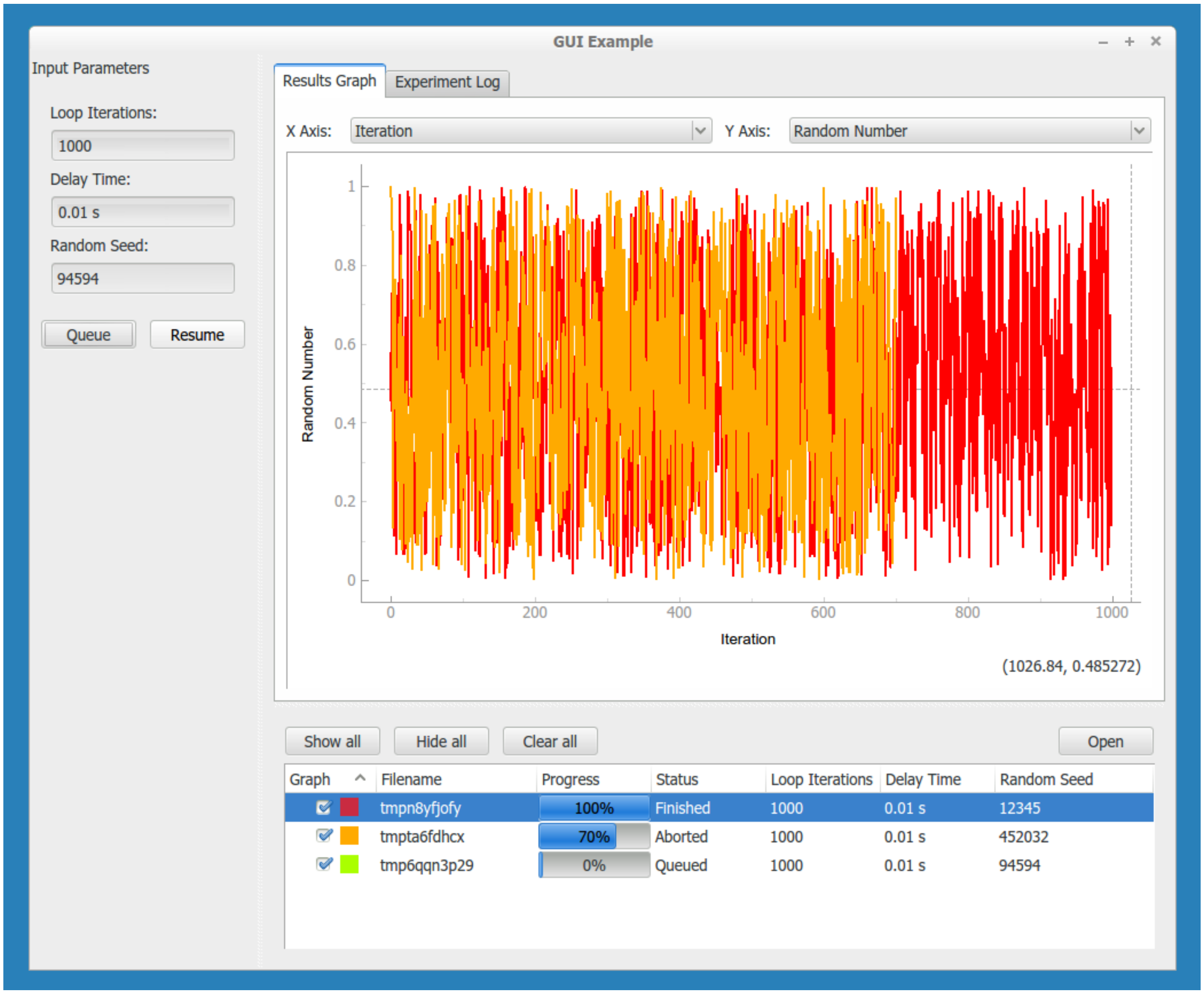


In the code, the MainWindow class is a sub-class of the ManagedWindow class. We override the constructor to provide information about the procedure class and its options. The `inputs` are a list of Parameters class-variable names, which the display will generate graphical fields for. When the list of 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.

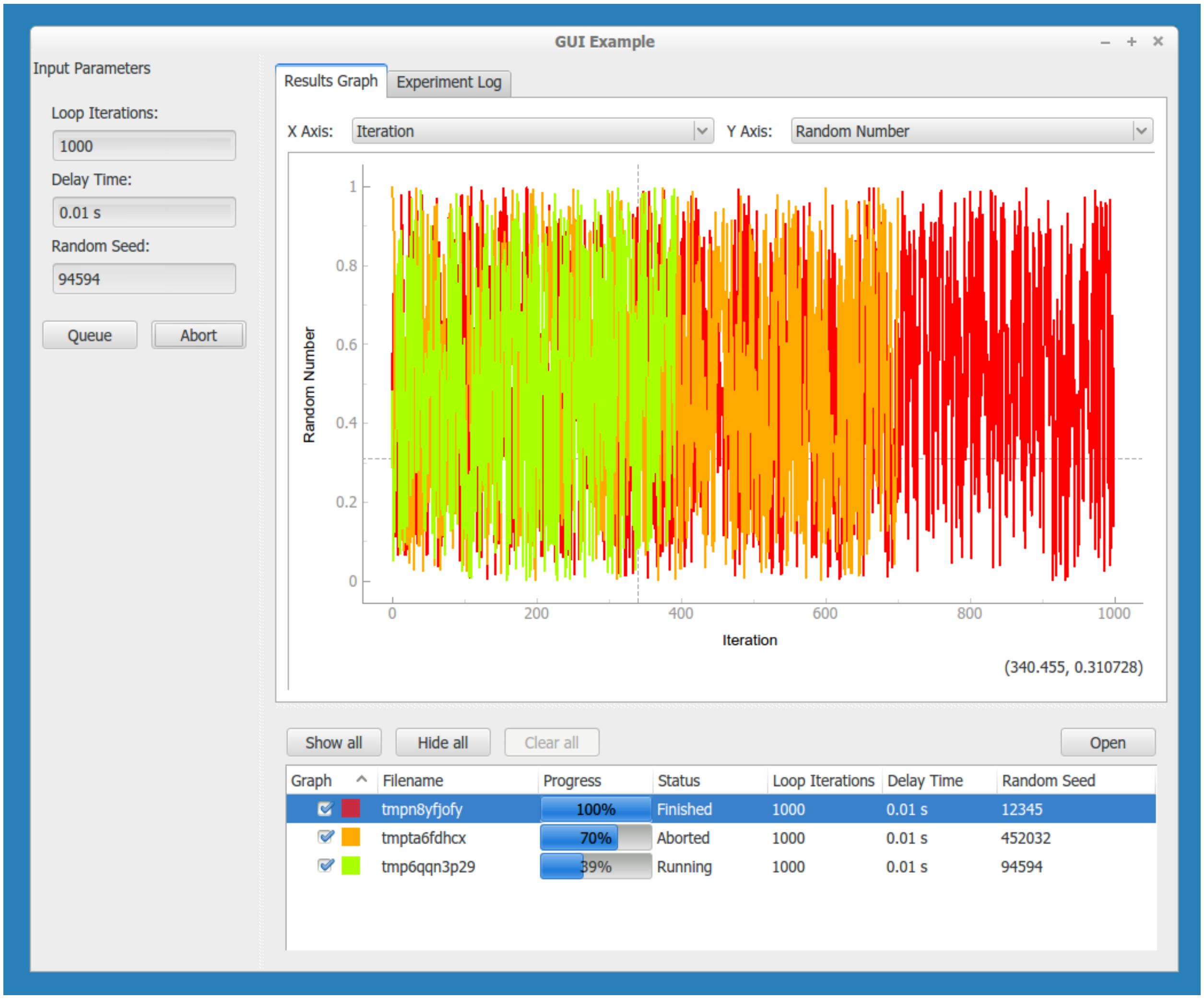
The queue method establishes how the Procedure object is constructed. We use the self.make_procedure method to create a Procedure based on the graphical input fields. Here we are free to modify the procedure before putting it on the queue. In this context, the Manager uses an Experiment object to keep 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.

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):
```

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```
        # use logarithmic x-axis (e.g. for frequency sweeps)
        plot.setLogMode(x=True)
```

For *ManagedWindow*, Similarly to the Plotter, the *setup_plot()* method can be overridden by your sub-class in order to do the set-up

```
class MainWindow(ManagedWindow):

    # ...

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

    # ...
```

It is also possible to access the *plot* attribute while outside of your sub-class, for example we could modify the previous section's example

```
if __name__ == "__main__":
    app = QtGui.QApplication(sys.argv)
    window = MainWindow()
    window.plot.setLogMode(x=True) # use logarithmic x-axis (e.g. for frequency␣
↪sweeps)
    window.show()
    sys.exit(app.exec_())
```

See pyqtgraph's API documentation on PlotItem for further details.

3.3.4 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):

```
class MainWindow(ManagedWindow):

    def __init__(self):
        super(MainWindow, self).__init__(
            procedure_class=TestProcedure,
            inputs=['iterations', 'delay', 'seed'],
            displays=['iterations', 'delay', 'seed'],
```

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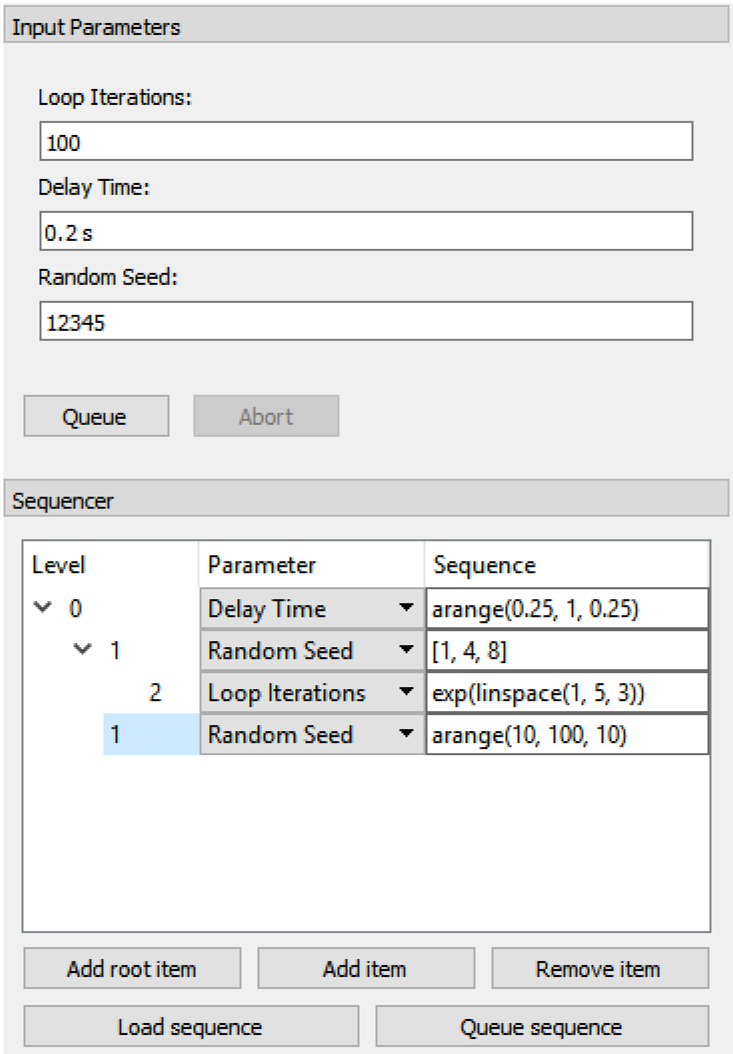
```
            x_axis='Iteration',
            y_axis='Random Number',
            sequencer=True,                                         # Added line
            sequencer_inputs=['iterations', 'delay', 'seed'],       # Added line
            sequence_file="gui_sequencer_example_sequence.txt",    # 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(MainWindow, self).__init__` call, as was done in the example.

CHAPTER 4

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**

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 inhereted from.

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'>*)
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

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 Fake adapter

class pymeasure.adapters.**FakeAdapter**
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'>*)
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

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.

4.3 Serial adapter

class pymeasure.adapters.**SerialAdapter**(*port*, ***kwargs*)
Bases: pymeasure.adapters.adapter.Adapter

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

Parameters

- **port** – Serial port
- **kwargs** – Any valid key-word argument for serial.Serial

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'>*)
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

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

4.4 Prologix adapter

class pymeasure.adapters.**PrologixAdapter**(*port*, *address=None*, *rw_delay=None*, *serial_timeout=0.5*, ***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.
- **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
```

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'>*)
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

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

4.5 VISA adapter

class pymeasure.adapters.**VISAAdapter**(*resourceName*, *visa_library=''*, ***kwargs*)
Bases: `pymeasure.adapters.adapter.Adapter`

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

Parameters

- **resource** – VISA resource name that identifies the address
- **visa_library** – VisaLibrary Instance, path of the VISA library or VisaLibrary spec string (@py or @ni). if not given, the default for the platform will be used.
- **kwargs** – Any valid key-word arguments for constructing a PyVISA 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*)
Writes a command to the instrument and returns a list of formatted values from the result. The format of the return is configurated by self.config().

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

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

config(*is_binary=False*, *datatype='str'*, *container=<built-in function array>*, *converter='s'*, *separator=', '*, *is_big_endian=False*)
Configurate the format of data transfer to and from the instrument.

Parameters

- **is_binary** – If True, data is in binary format, otherwise ASCII.
- **datatype** – Data type.
- **container** – Return format. Any callable/type that takes an iterable.
- **converter** – String converter, used in dealing with ASCII data.
- **separator** – Delimiter of a series of data in ASCII.
- **is_big_endian** – Endianness.

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'>*)
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

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

4.6 VXI-11 adapter

class pymeasure.adapters.**VXI11Adapter** (*host*, ***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.

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'>*)
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

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

CHAPTER 5

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.

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

pcolor(*xname*, *yname*, *zname*, **args*, ***kwargs*)
Plot the results from the experiment.data pandas dataframe in a pcolor graph. Store the plots in a plots list attribute.

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_pcolor(*ax*, *xname*, *yname*, *zname*)
Update a pcolor 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()

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.

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.

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*)
`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*, ***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)
- **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.

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

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*)

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

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.**unique_filename**(*directory*, *prefix='DATA'*, *suffix=''*, *ext='csv'*, *dated_folder=False*, *index=True*, *datetimeformat='%Y-%m-%d'*)
Returns a unique filename based on the directory and prefix

CHAPTER 6

pymeasure.display

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

6.1 Browser classes

class pymeasure.display.browser.**Browser**(*procedure_class*, *display_parameters*, *measured_quantities*, *sort_by_filename=False*, *parent=None*)

Bases: sphinx.ext.autodoc.importer._MockObject

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**(*results*, *curve*, *parent=None*)

Bases: sphinx.ext.autodoc.importer._MockObject

6.2 Curves classes

class pymeasure.display.curves.**BufferCurve**(*errors=False*, ***kwargs*)

Bases: sphinx.ext.autodoc.importer._MockObject

Creates a curve based on a predefined buffer size and allows data to be added dynamically, in additon to supporting error bars

append(*x*, *y*, *xError=None*, *yError=None*)
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**(*plot*, *pen=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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**(*results*, *x*, *y*, *xerr=None*, *yerr=None*, *force_reload=False*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject

Creates a curve loaded dynamically from a file through the Results object and supports error bars. 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()
Updates the data by polling the results

class pymeasure.display.curves.**ResultsImage**(*results*, *x*, *y*, *z*, *force_reload=False*)
Bases: sphinx.ext.autodoc.importer._MockObject

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

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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.

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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**(*parameter*, *parent=None*, ***kwargs*)
Bases: sphinx.ext.autodoc.importer._MockObject, *pymeasure.display.inputs.Input*

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**(*queue*)
Bases: sphinx.ext.autodoc.importer._MockObject

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

class pymeasure.display.listeners.**QListener**(*port*, *topic=”*, *timeout=0.01*)
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**(*parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject, logging.Handler

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**(*results*, *curve*, *browser_item*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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

Parameters

- **results** – *Results* object
- **curve** – *ResultsCurve* object
- **browser_item** – *BrowserItem* object

class pymeasure.display.manager.**ExperimentQueue**
Bases: sphinx.ext.autodoc.importer._MockObject

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.**ImageExperiment** (*results*, *curve*, *image*, *browser_item*, *parent=None*)
Bases: *pymeasure.display.manager.Experiment*

Adds saving of the experiments image to *Experiment*. Needed to make image features work

class pymeasure.display.manager.**ImageExperimentQueue**
Bases: *pymeasure.display.manager.ExperimentQueue*

Overwrites needed features from *ExperimentQueue* to make image features work

class pymeasure.display.manager.**ImageManager** (*plot*, *im_plot*, *browser*, *port=5888*, *log_level=20*, *parent=None*)
Bases: *pymeasure.display.manager.Manager*

Overwrites needed features from *Manager* to make image features work

load (*experiment*)
Load a previously executed Experiment

remove (*experiment*)
Removes an Experiment

class pymeasure.display.manager.**Manager** (*plot*, *browser*, *port=5888*, *log_level=20*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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*)
Bases: `pymeasure.thread.StoppableThread`

Plotter dynamically plots data from a file through the Results object and supports error bars.

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**(*parent=None*)
Bases: `sphinx.ext.autodoc.importer._MockObject`

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.**BrowserWidget**(**args*, *parent=None*)
Bases: `sphinx.ext.autodoc.importer._MockObject`

class pymeasure.display.widgets.**ImageFrame**(*x_axis*, *y_axis*, *z_axis=None*, *refresh_time=0.2*, *check_status=True*, *parent=None*)
Bases: `sphinx.ext.autodoc.importer._MockObject`

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

parse_axis(*axis*)
Returns the units of an axis by searching the string

class pymeasure.display.widgets.**ImageWidget**(*columns*, *x_axis*, *y_axis*, *z_axis=None*, *refresh_time=0.2*, *check_status=True*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

Extends the PlotFrame to allow different columns of the data to be dynamically choosen

new_image(*results*)
Creates a new image

class pymeasure.display.widgets.**InputsWidget**(*procedure_class*, *inputs=()*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

get_procedure()
Returns the current procedure

class pymeasure.display.widgets.**LogWidget**(*parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

class pymeasure.display.widgets.**PlotFrame**(*x_axis=None*, *y_axis=None*, *refresh_time=0.2*, *check_status=True*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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

parse_axis(*axis*)
Returns the units of an axis by searching the string

class pymeasure.display.widgets.**PlotWidget**(*columns*, *x_axis=None*, *y_axis=None*, *refresh_time=0.2*, *check_status=True*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

Extends the PlotFrame to allow different columns of the data to be dynamically choosen

class pymeasure.display.widgets.**ResultsDialog**(*columns*, *x_axis=None*, *y_axis=None*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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

Raised when the evaluation of a sequence string goes wrong.

class pymeasure.display.widgets.**SequencerWidget**(*inputs=None*, *sequence_file=None*, *parent=None*)
Bases: sphinx.ext.autodoc.importer._MockObject

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.

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.

6.11 Windows classes

class pymeasure.display.windows.**ManagedImageWindow** (*procedure_class, x_axis, y_axis, z_axis=None, inputs=(), displays=(), log_channel=”, log_level=20, parent=None*)

Bases: sphinx.ext.autodoc.importer._MockObject

Abstract base class.

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

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

See also:

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

plot

The pyqtgraph.PlotItem object for this window. Can be accessed to further customise the plot view programmatically, e.g., display log-log or semi-log axes by default, change axis range, etc.

queue ()

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.

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.

setup_im_plot (*im_plot*)
This method does nothing by default, but can be overridden by the child class in order to set up custom options for the image plot

This method is called during the constructor, after all other set up has been completed, and is provided as a convenience method to parallel Plotter.

Parameters **im_plot** – This window's ImageItem instance.

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

This method is called during the constructor, after all other set up has been completed, and is provided as a convenience method to parallel Plotter.

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

class pymeasure.display.windows.**ManagedWindow** (*procedure_class, inputs=(), displays=(), x_axis=None, y_axis=None, log_channel='', log_level=20, parent=None, sequencer=False, sequencer_inputs=None, sequence_file=None, inputs_in_scrollarea=False*)

Bases: sphinx.ext.autodoc.importer._MockObject

Abstract base class.

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

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

See also:

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

plot
The pyqtgraph.PlotItem object for this window. Can be accessed to further customise the plot view programmatically, e.g., display log-log or semi-log axes by default, change axis range, etc.

queue ()
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.

For example:

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

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```
    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.

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

This method is called during the constructor, after all other set up has been completed, and is provided as a convenience method to parallel Plotter.

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

class pymeasure.display.windows.**PlotterWindow**(*plotter*, *refresh_time=0.1*, *parent=None*)
Bases: `sphinx.ext.autodoc.importer._MockObject`

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 7

pymeasure.instruments

This section contains documentation on the instrument classes.

7.1 Instrument classes

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

This provides the base class for all Instruments, which is independent of the particular Adapter used to connect for communication to the instrument. It provides basic SCPI commands by default, but can be toggled with `includeSCPI`.

Parameters

- **adapter** – An *Adapter* object
- **name** – A string name
- **includeSCPI** – A boolean, which toggles the inclusion of standard SCPI commands

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()

Return any accumulated errors. Must be reimplemented by subclasses.

clear()

Clears the instrument status byte

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>>*, *check_set_errors=False*, *check_get_errors=False*, ***kwargs*)

Returns a property for the class based on the supplied commands. This property may be set and read from the instrument.

Parameters

- **get_command** – A string command that asks for the value
- **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
- **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
- **check_set_errors** – Toggles checking errors after setting
- **check_get_errors** – Toggles checking errors after getting

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*, ***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 both getting and setting
- **check_get_errors** – Toggles checking errors after getting

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*, ***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

shutdown()
Brings the instrument to a safe and stable state

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.**Mock**(*wait=0.1*, ***kwargs*)
Bases: `pymeasure.instruments.instrument.Instrument`

Mock instrument for testing.

get_time()
Get elapsed time

get_voltage()
Get the voltage.

get_wave()
Get wave.

reset_time()
Reset the timer to 0 s.

set_output_voltage(*value*)
Set the voltage.

set_time(*value*)
Wait for the timer to reach the specified time. If value = 0, reset.

time
Get elapsed time

voltage
Get the voltage.

wave
Get wave.

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*)
Join a list of validators together as a single. Expects a list of validator functions and values.

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 the maximum and greater than the minimum of the range. 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.

center_frequency
Center Frequency in Hz

id
Reads the instrument identification

span_frequency
Span Frequency in Hz

start_frequency
Starting frequency in Hz

stop_frequency
Stoping frequency in Hz

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
```

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

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'.

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.

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.

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

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

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

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

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.

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'.

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

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

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.

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

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.

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'.

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.

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

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.

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

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

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.

data
Returns the real and imaginary data from the last scan

disable_averaging()
Disables averaging

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=1*, *blocking=True*, *timeout=25*, *delay=0.1*)
Initiates a scan with the number of averages specified and blocks until the operation is complete if blocking is True

scan_continuous()
Initiates a continuous scan

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*)
Turns on averaging of a specific number between 0 and 999

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

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

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

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

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

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

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

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

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

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

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

ac_current
AC current level, in Amps

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`

frequency
AC frequency (range depending on model), in Hertz

impedance
Measured data A and B, according to `mode`

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]

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

current_ac
AC current, in Amps

current_dc
DC current, in Amps

resistance
Resistance, in Ohms

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

voltage_ac
AC voltage, in Volts

voltage_dc
DC voltage, in Volts

7.6.6 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
       },

       "VAR2": {
           "start" : 0,
           "step" : 10e-6,
```

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```
            "points" : 3,
            "compliance" : 2

        }
    }
```

analyzer_mode
A string property that controls the instrument operating mode.

- Values: SWEEP, SAMPLING

```
smu.analyzer_mode = "SWEEP"
```

configure(*config_file*)
Convenience function to configure the channel setup and sweep using a JSON (JavaScript Object Notation) configuration file.

Parameters **config_file** – JSON file to configure instrument channels.

```
instr.configure('config.json')
```

data_variables
Gets 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
```

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*)
Gets 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')
```

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.
```

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

channel_function
A string property that controls the SMU<n> channel function.

- Values: VAR1, VAR2, VARD or CONS.

```
instr.smu1.channel_function = "VAR1"
```

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"
```

compliance

This command 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
```

constant_value

This command sets 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
```

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"
```

disable

This command deletes the settings of SMU<n>.

```
instr.smu1.disable()
```

series_resistance

This command controls the series resistance of SMU<n>.

- Values: `0OHM`, `10KOHM`, `100KOHM`, or `1MOHM`

```
instr.smu1.series_resistance = "10KOHM"
```

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.

spacing

This command 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.

points

This command 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.

compliance

This command sets the sweep COMPLIANCE value of VARD.

```
instr.vard.compliance = 0.1
```

offset

This command 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
```

ratio

This command 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

compliance

Sets the sweep COMPLIANCE value.

```
instr.var1.compliance = 0.1
```

start

Sets the sweep START value.

```
instr.var1.start = 0
```

step

Sets the sweep STEP value.

```
instr.var1.step = 0.1
```

stop

Sets the sweep STOP value.

```
instr.var1.stop = 3
```

class pymeasure.instruments.agilent.agilent4156.**VMU**(*resourceName*, *channel*, ***kwargs*)

Bases: pymeasure.instruments.instrument.Instrument

channel_mode

A string property that controls the VMU<n> channel mode.

- Values: V, DVOL

disable

This command disables the settings of VMU<n>.

```
instr.vmu1.disable()
```

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

channel_function

A string property that controls the VSU channel function.

- Value: VAR1, VAR2, VARD or CONS.

channel_mode

Get channel mode of VSU<n>.

constant_value

This command sets the constant source value of VSU<n>.

```
instr.vsu1.constant_value = 0
```

disable

This command deletes the settings of VSU<n>.

```
instr.vsu1.disable()
```

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"
```

7.6.7 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 = True                # Enable burst mode
wfg.burst_ncycles = 10e3        # 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"

wfg.check_errors()              # Get the error queue
```

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.

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.

beeper_state
A boolean property that controls the state of the beeper. Can be set.

burst_mode
A string property that controls the burst mode. Valid values are: TRIG<GERED>, GAT<ED>. This setting can be set.

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.

burst_state
A boolean property that controls whether the burst mode is on (True) or off (False). Can be set.

check_errors()
Read all errors from the instrument.

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.

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.

output
A boolean property that turns on (True) or off (False) the output of the function generator. Can be set.

pulse_dutycycle
A floating point property that controls the duty cycle of a pulse waveform function in percent. Can be set.

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>.

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.

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. Can be set.

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.

ramp_symmetry
A floating point property that controls the symmetry percentage for the ramp waveform. Can be set.

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.

shape
A string property that controls the output waveform. Can be set to: SIN<USOID>, SQU<ARE>, RAMP, PULS<E>, NOIS<E>, DC, USER.

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.

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.

trigger_state
A boolean property that controls whether the output is triggered (True) or not (False). Can be set.

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.

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.

7.6.8 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'
```

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.

amplitude_unit
A string property that controls the units of the amplitude. Valid values are VPP (default), VRMS, and DBM. Can be set.

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).

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.

arb_filter
A string property that selects the filter setting for arbitrary signals. Can be set to 'NORM<AL>', 'STEP' and 'OFF'.

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.

burst_mode
A string property that controls the burst mode. Valid values are: TRIG<GERED>, GAT<ED>. This setting can be set.

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.

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.

burst_state
A boolean property that controls whether the burst mode is on (True) or off (False). Can be set.

check_errors()
Read all errors from the instrument.

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.

display
A string property which is displayed on the front panel of the device. Can be set.

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.

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.

id
Reads the instrument identification

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.

output
A boolean property that turns on (True, 'on') or off (False, 'off') the output of the function generator. Can be set.

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.

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.

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>.

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.

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.

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.

ramp_symmetry
A floating point property that controls the symmetry percentage for the ramp waveform, from 0.0% to 100.0% Can be set.

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.

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.

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.

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.

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.

7.6.9 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*.

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.

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.

7.7 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

adc1
Reads the input value of ADC1 in Volts

adc2
Reads the input value of ADC2 in Volts

adc3
Reads the input value of ADC3 in Volts

adc4
Reads the input value of ADC4 in Volts

dac1
A floating point property that represents the output value on DAC1 in Volts. This property can be set.

dac2
A floating point property that represents the output value on DAC2 in Volts. This property can be set.

dac3
A floating point property that represents the output value on DAC3 in Volts. This property can be set.

dac4
A floating point property that represents the output value on DAC4 in Volts. This property can be set.

frequency
A floating point property that represents the lock-in frequency in Hz. This property can be set.

harmonic
An integer property that represents the reference harmonic mode control, taking values from 1 to 127. This property can be set.

id
Reads the instrument identification

mag
Reads the magnitude in Volts

phase
A floating point property that represents the reference harmonic phase in degrees. This property can be set.

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

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.

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.

voltage
A floating point property that represents the voltage in Volts. This property can be set.

x
Reads the X value in Volts

x1
Reads the first harmonic X value in Volts

x2
Reads the second harmonic X value in Volts

xy
Reads both the X and Y values in Volts

y
Reads the Y value in Volts

y1
Reads the first harmonic Y value in Volts

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
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
```

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.

field
Reads the field in kGauss of the magnet.

has_persistent_switch_enabled()
Returns a boolean if the persistent switch is enabled.

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.

ramp_rate_current
A floating point property that sets the current ramping rate in A/s.

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.

state
Reads the field in kGauss of the magnet.

supply_current
Reads the current in Amps of the power supply.

target_current
A floating point property that sets the target current in A for the magnet.

target_field
A floating point property that sets the target field in kGauss for the magnet.

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 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*.

7.9.1 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.

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

output
A boolean property that represents the signal output state. This property can be set to control the output.

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.

7.9.2 Anritsu MS9710C Optical Spectrum Analyzer

class pymeasure.instruments.anritsu.**AnritsuMS9710C**(*adapter*, ***kwargs*)
Bases: pymeasure.instruments.instrument.Instrument

Anritsu MS9710C Optical Spectrum Analyzer.

analysis
Analysis Control

analysis_result
Read back anaysis result from current scan.

average_point
Number of averages to take on each point (2-1000), or OFF

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.

data_memory_a_condition
Returns the data condition of data memory register A. Starting wavelength, and a sampling point (l1, l2, n).

data_memory_a_size
Returns the number of points sampled in data memory register A.

data_memory_a_values
Reads the binary data from memory register A.

data_memory_b_condition
Returns the data condition of data memory register B. Starting wavelength, and a sampling point (l1, l2, n).

data_memory_b_size
Returns the number of points sampled in data memory register B.

data_memory_b_values
Reads the binary data from memory register B.

data_memory_select
Memory Data Select.

dip_search
Dip Search Mode

ese2
Extended Event Status Enable Register 2

esr2
Extended Event Status Register 2

level_lin
Level Linear Scale (/div)

level_log
Level Log Scale (/div)

level_opt_attn
Optical Attenuation Status (ON/OFF)

level_scale
Current Level Scale

measure_mode
Returns the current Measure Mode the OSA is in.

measure_peak()
Measure the peak and return the trace marker.

peak_search
Peak Search Mode

read_memory(*slot='A'*)
Read the scan saved in a memory slot.

resolution
Resolution (nm)

resolution_actual
Resolution Actual (ON/OFF)

resolution_vbw
Video Bandwidth Resolution

sampling_points
Number of sampling points

single_sweep(***kwargs*)
Perform a single sweep and wait for completion.

trace_marker
Sets the trace marker with a wavelength. Returns the trace wavelength and power.

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.

wavelength_center
Center Wavelength of Spectrum Scan in nm.

wavelength_marker_value
Wavelength Marker Value (wavelength or freq.?)

wavelength_span
Wavelength Span of Spectrum Scan in nm.

wavelength_start
Wavelength Start of Spectrum Scan in nm.

wavelength_stop
Wavelength Stop of Spectrum Scan in nm.

wavelength_value_in
Wavelength value in Vacuum or Air

wavelengths
Return a numpy array of the current wavelengths of scans.

7.10 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*.

7.10.1 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

7.10.2 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

current
The actual current in Amps. This property can be set through *current_ppm*.

current_ppm
The current in parts per million. This property can be set.

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.

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.

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)

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

status
A list of human-readable strings that contain the instrument status information, based on `status_hex`.

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

7.11 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*.

7.11.1 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
```

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.

max_current
A floating point property that represents the maximum output current of the power supply in Amps. This property can be set.

max_voltage
A floating point property that represents the maximum output voltage of the power supply in Volts. This property can be set.

measure_current
Measures the actual output current of the power supply in Amps.

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)

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.

voltage
A floating point property that represents the output voltage setting of the power supply in Volts. This property can be set.

7.12 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*.

7.12.1 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.

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

id
Reads the idenfitication information.

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.

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.

7.13 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*.

7.13.1 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.

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`.

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.

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*.

max_amplitude
Reads the maximum *amplitude* in Volts for the given shape

max_frequency
Reads the maximum *frequency* in Hz for the given shape

max_offset
Reads the maximum *offset* in Volts for the given shape

min_amplitude
Reads the minimum *amplitude* in Volts for the given shape

min_frequency
Reads the minimum *frequency* in Hz for the given shape

min_offset
Reads the minimum *offset* in Volts for the given shape

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*.

shape
A string property that controls the shape of the wave, which can take the values: sinusoid, square, triangle, ramp, noise, dc, and user.

7.13.2 HP 34401A Multimeter

class pymeasure.instruments.hp.**HP34401A**(*resourceName*, ***kwargs*)
Bases: pymeasure.instruments.instrument.Instrument

Represents the HP 34401A instrument.

current_ac
AC current, in Amps

current_dc
DC current, in Amps

resistance
Resistance, in Ohms

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

voltage_ac
AC voltage, in Volts

voltage_dc
DC voltage, in Volts

7.14 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*.

7.14.1 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

beep_state

A string property that enables or disables the system status beeper, which can take the values: :code:'enabled' and :code:'disabled'.

buffer_data

Returns a numpy array of values from the buffer.

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.

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.

current

Reads a DC or AC current measurement in Amps, based on the active *mode*.

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.

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.

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.

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.

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.

current_digits
An integer property that controls the number of digits in the DC current readings, which can take values from 4 to 7.

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.

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.

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

frequency
Reads a frequency measurement in Hz, based on the active *mode*.

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.

frequency_digits
An integer property that controls the number of digits in the frequency readings, which can take values from 4 to 7.

frequency_reference
A floating point property that controls the frequency reference value in Hz, which can take values from 0 to 15 MHz.

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.

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

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'.

period
Reads a period measurement in seconds, based on the active *mode*.

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.

period_digits
An integer property that controls the number of digits in the period readings, which can take values from 4 to 7.

period_reference
A floating point property that controls the period reference value in seconds, which can take values from 0 to 1 s.

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.

resistance
Reads a resistance measurement in Ohms for both 2-wire and 4-wire configurations, based on the active *mode*.

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.

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.

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.

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.

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.

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.

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.

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.

stop_buffer()
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

temperature
Reads a temperature measurement in Celsius, based on the active `mode`.

temperature_digits
An integer property that controls the number of digits in the temperature readings, which can take values from 4 to 7.

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.

temperature_reference
A floating point property that controls the temperature reference value in Celsius, which can take values from -200 to 1372 C.

trigger_count
An integer property that controls the trigger count, which can take values from 1 to 9,999.

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.

voltage
Reads a DC or AC voltage measurement in Volts, based on the active `mode`.

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.

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.

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.

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.

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.

voltage_digits
An integer property that controls the number of digits in the DC voltage readings, which can take values from 4 to 7.

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.

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.

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

7.14.2 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
```

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```
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_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.

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

buffer_data
Returns a numpy array of values from the buffer.

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.

compliance_current
A floating point property that controls the compliance current in Amps.

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.

current
Reads the current in Amps, if configured for this reading.

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.

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.

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.

error
Returns a tuple of an error code and message from a single error.

id
Requests and returns the identification of the instrument.

is_buffer_full()
Returns True if the buffer is full of measurements.

max_current
Returns the maximum current from the buffer

max_resistance
Returns the maximum resistance from the buffer

max_voltage
Returns the maximum voltage from the buffer

maximums
Returns the calculated maximums for voltage, current, and resistance from the buffer data as a list.

mean_current
Returns the mean current from the buffer

mean_resistance
Returns the mean resistance from the buffer

mean_voltage
Returns the mean voltage from the buffer

means
Reads the calculated means (averages) for voltage, current, and resistance from the buffer data as a list.

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

min_current
Returns the minimum current from the buffer

min_resistance
Returns the minimum resistance from the buffer

min_voltage
Returns the minimum voltage from the buffer

minimums
Returns the calculated minimums for voltage, current, and resistance from the buffer data as a list.

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.

resistance
Reads the resistance in Ohms, if configured for this reading.

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.

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.

source_current
A floating point property that controls the source current in Amps.

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.

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].

source_delay_auto
A boolean property that enables or disables auto delay. Valid values are True and False.

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.

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.

source_voltage
A floating point property that controls the source voltage in Volts.

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.

standard_devs
Returns the calculated standard deviations for voltage, current, and resistance from the buffer data as a list.

start_buffer()
Starts the buffer.

std_current
Returns the current standard deviation from the buffer

std_resistance
Returns the resistance standard deviation from the buffer

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.

trigger_count
An integer property that controls the trigger count, which can take values from 1 to 9,999.

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 `GET` or `*TRG`.

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.

voltage
Reads the voltage in Volts, if configured for this reading.

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.

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

wires
An integer property that controls the number of wires in use for resistance measurements, which can take the value of 2 or 4.

7.14.3 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
```

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```
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

buffer_data
Returns a numpy array of values from the buffer.

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.

compliance_current
A floating point property that controls the compliance current in Amps.

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.

current
Reads the current in Amps, if configured for this reading.

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.

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.

error
Returns a tuple of an error code and message from a single error.

id
Requests and returns the identification of the instrument.

is_buffer_full()
Returns True if the buffer is full of measurements.

max_current
Returns the maximum current from the buffer

max_resistance
Returns the maximum resistance from the buffer

max_voltage
Returns the maximum voltage from the buffer

maximums
Returns the calculated maximums for voltage, current, and resistance from the buffer data as a list.

mean_current
Returns the mean current from the buffer

mean_resistance
Returns the mean resistance from the buffer

mean_voltage
Returns the mean voltage from the buffer

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

min_current
Returns the minimum current from the buffer

min_resistance
Returns the minimum resistance from the buffer

min_voltage
Returns the minimum voltage from the buffer

minimums
Returns the calculated minimums for voltage, current, and resistance from the buffer data as a list.

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.

resistance
Reads the resistance in Ohms, if configured for this reading.

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.

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.

source_current
A floating point property that controls the source current in Amps.

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.

source_enabled
Reads a boolean value that is True if the source is enabled.

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.

source_voltage
A floating point property that controls the source voltage in Volts.

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.

standard_devs
Returns the calculated standard deviations for voltage, current, and resistance from the buffer data as a list.

start_buffer()
Starts the buffer.

std_current
Returns the current standard deviation from the buffer

std_resistance
Returns the resistance standard deviation from the buffer

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.

voltage
Reads the voltage in Volts, if configured for this reading.

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.

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

wires
An integer property that controls the number of wires in use for resistance measurements, which can take the value of 2 or 4.

7.14.4 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

buffer_data
Returns a numpy array of values from the buffer.

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

closed_channels
Parameter that controls the opened and closed channels. All mentioned channels are closed, other channels will be opened.

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.

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.

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

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.

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

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.

stop_buffer()
Aborts the buffering measurement, by stopping the measurement arming and triggering sequence. If possible, a Selected Device Clear (SDC) is used.

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

7.14.5 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

buffer_data

Returns a numpy array of values from the buffer.

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.

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.

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.

error
Returns a tuple of an error code and message from a single error.

id
Requests and returns the identification of the instrument.

is_buffer_full()
Returns True if the buffer is full of measurements.

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.

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.

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.

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.

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

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.

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.

source_auto_range
A boolean property that controls the auto range of the current source. Valid values are True or False.

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].

source_current
A floating point property that controls the source current in Amps.

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].

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.

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.

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.

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.

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.

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 `GET` or `*TRG`.

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.

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.

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.

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.

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.

waveform_frequency
A floating point property that controls the frequency of the waveform in Hertz. Valid values are in range 1e-3 to 1e5.

waveform_function
A string property that controls the selected wave function. Valid values are "sine", "ramp", "square", "arbitrary1", "arbitrary2", "arbitrary3" and "arbitrary4".

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.

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

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.

7.14.6 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()
Return any accumulated errors. Must be reimplemented by subclasses.

close(*channel*)
Closes (connects) the specified channel.

Parameters **channel** (*int*) – 3-digit number for the channel

Returns None

closed_channels
Reads the list of closed channels

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

reset()
Resets the instrument.

shutdown()
Brings the instrument to a safe and stable state

7.15 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*.

7.15.1 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.

current
Reads a setting current in Amps.

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.

id
Requests and returns the identification of the instrument.

is_enabled()
Returns True if the current supply is enabled.

reset()
Resets the instrument.

shutdown()
Brings the instrument to a safe and stable state

voltage
Reads a DC voltage measurement in Volts.

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.

7.16 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*.

7.16.1 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

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'>*)
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

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

7.16.2 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.

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.

setpoint_1
A floating point property that controls the setpoint temperature in Kelvin for Loop 1.

setpoint_2
A floating point property that controls the setpoint temperature in Kelvin for Loop 2.

temperature_A
Reads the temperature of the sensor A in Kelvin.

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

7.16.3 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

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

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.

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

7.17 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*.

7.17.1 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.

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.

error
Reads an error code from the motion controller.

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.

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.

left_limit
A floating point property that controls the left software limit of the axis.

motion_done
Returns a boolean that is True if the motion is finished.

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.

right_limit
A floating point property that controls the right software limit of the axis.

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.

7.18 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*.

7.18.1 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)
```

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```
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.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.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

:param dmm_function:DMM function index or name:

- 'DC_VOLTS', 'AC_VOLTS'
- 'DC_CURRENT', 'AC_CURRENT'
- 'RESISTANCE'
- 'DIODE'

Parameters

- **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.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 %

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.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.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.

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.

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**(*device_name=''*, *name='VirtualBench'*)
Bases: sphinx.ext.autodoc.importer._MockObject

Represents National Instruments Virtual Bench main frame. This class provides direct access to the armstrap/pyvirtualbench Python wrapper.

7.19 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*.

7.19.1 Oxford Instrument Intelligent Temperature Controller 503

class pymeasure.instruments.oxfordinstruments.**ITC503**(*resourceName*, *clear_buffer=True*, ***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
```

auto_pid
A boolean property that sets the Auto-PID mode on (True) or off (False).

control_mode
A string property that sets the ITC in LOCAL or REMOTE and LOCKES, or UNLOCKES, the LOC/REM button. Allowed values are: LL: LOCAL & LOCKED RL: REMOTE & LOCKED LU: LOCAL & UNLOCKED RU: REMOTE & UNLOCKED.

heater_gas_mode
A string property that sets the heater and gas flow control to AUTO or MANUAL. Allowed values are: MANUAL: HEATER MANUAL, GAS MANUAL AM: HEATER AUTO, GAS MANUAL MA: HEATER MANUAL, GAS AUTO AUTO: HEATER AUTO, GAS AUTO.

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

sweep_status
An integer property that sets the sweep status. Values are: 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.

sweep_table
A property that sets values in the sweep table. Relies on the xpointer and ypointer to point at the location in the table that is to be set.

temperature_1
Reads the temperature of the sensor 1 in Kelvin.

temperature_2
Reads the temperature of the sensor 2 in Kelvin.

temperature_3
Reads the temperature of the sensor 3 in Kelvin.

temperature_error
Reads the difference between the set-point and the measured temperature in Kelvin. Positive when set-point is larger than measured.

temperature_setpoint
A floating point property that controls the temperature set-point of the ITC in kelvin.

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 set to zero, 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.

xpointer
An integer property to set pointers into tables for loading and examining values in the table. For programming the sweep table values from 1 to 16 are allowed, corresponding to the maximum number of steps.

ypointer
An integer property to set pointers into tables for loading and examining values in the table. For programming the sweep table the allowed values are: 1: Setpoint temperature, 2: Sweep-time to set-point, 3: Hold-time at set-point.

7.20 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*.

7.20.1 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

angle
Returns the angle in degrees based on the position and whether relative or absolute positioning is enabled, returning None on error

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

position
Returns an integer number of counts that correspond to the angular position where 1 revolution equals 4000 counts

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

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

7.21 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*.

7.21.1 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

adc1
Reads the input value of ADC1 in Volts

adc2
Reads the input value of ADC2 in Volts

dac1
A floating point property that represents the output value on DAC1 in Volts. This property can be set.

dac2
A floating point property that represents the output value on DAC2 in Volts. This property can be set.

dac3
A floating point property that represents the output value on DAC3 in Volts. This property can be set.

dac4
A floating point property that represents the output value on DAC4 in Volts. This property can be set.

frequency
A floating point property that represents the lock-in frequency in Hz. This property can be set.

harmonic
An integer property that represents the reference harmonic mode control, taking values from 1 to 65535. This property can be set.

id
Reads the instrument identification

mag
Reads the magnitude in Volts

phase
A floating point property that represents the reference harmonic phase in degrees. This property can be set.

reference
Controls the oscillator reference. Can be "internal", "external rear" or "external front"

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.

setDifferentialMode(*lineFiltering=True*)
Sets lockin to differential mode, measuring A-B

shutdown()
Brings the instrument to a safe and stable state

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.

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.

values(*command*)
Rewrite the method because of extra character in return string.

voltage
A floating point property that represents the voltage in Volts. This property can be set.

x
Reads the X value in Volts

xy
Reads both the X and Y values in Volts

y
Reads the Y value in Volts

7.22 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*.

7.22.1 SR830 Lock-in Amplifier

class pymeasure.instruments.srs.**SR830**(*resourceName*, ***kwargs*)

Bases: pymeasure.instruments.instrument.Instrument

adc1
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

adc2
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

adc3
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

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

aux_in_1
Reads the Aux input 1 value in Volts with 1/3 mV resolution.

aux_in_2
Reads the Aux input 2 value in Volts with 1/3 mV resolution.

aux_in_3
Reads the Aux input 3 value in Volts with 1/3 mV resolution.

aux_in_4
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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

harmonic
An integer property that controls the harmonic that is measured. Allowed values are 1 to 19999. Can be set.

input_config
An string property that controls the input configuration. Allowed values are: ['A', 'A - B', 'I (1 MOhm)', 'I (100 MOhm)']

input_coupling
An string property that controls the input coupling. Allowed values are: ['AC', 'DC']

input_grounding
An string property that controls the input shield grounding. Allowed values are: ['Float', 'Ground']

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

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)

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

reference_source
An string property that controls the reference source. Allowed values are: ['External', 'Internal']

sample_frequency
Gets the sample frequency in Hz

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)

sine_voltage
A floating point property that represents the reference sine-wave voltage in Volts. This property can be set.

theta
Reads the theta value in degrees.

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

x
Reads the X value in Volts.

y
Reads the Y value in Volts.

7.23 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*.

7.23.1 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

7.23.2 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

7.24 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*.

7.24.1 Thorlabs PM100USB Powermeter

class pymeasure.instruments.thorlabs.**ThorlabsPM100USB**(*adapter*, ***kwargs*)

Bases: pymeasure.instruments.instrument.Instrument

Represents Thorlabs PM100USB powermeter

measure_power(*wavelength*)

Set wavelength in nm and get power in W If wavelength is out of range it will be set to range limit

power

Power, in Watts

sensor()

Get sensor info

wavelength

Wavelength in nm; not set outside of range

wavelength_max

Get maximum wavelength, in nm

wavelength_min

Get minimum wavelength, in nm

class pymeasure.instruments.thorlabs.**ThorlabsPro8000**(*resourceName*, ***kwargs*)

Bases: pymeasure.instruments.instrument.Instrument

Represents Thorlabs Pro 8000 modular laser driver

LDCCurrent

Laser current.

LDCCurrentLimit

Set Software current Limit (value must be lower than hardware current limit).

LDCPolarity

Set laser diode polarity. Allowed values are: [‘AG’, ‘CG’]

LDCStatus

Set laser diode status. Allowed values are: [‘ON’, ‘OFF’]

TEDSetTemperature

Set TEC temperature

TEDStatus

Set TEC status. Allowed values are: [‘ON’, ‘OFF’]

slot

Slot selection. Allowed values are: range(1, 9)

7.25 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*.

7.25.1 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*, *complinance_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*, *complinance_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.

compliance_current
A floating point property that sets the compliance current in Amps, which can take values from 5 to 120 mA.

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.

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.

source_current
A floating point property that controls the source current in Amps, if that mode is active.

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.

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.

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.

source_voltage
A floating point property that controls the source voltage in Volts, if that mode is active.

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.

CHAPTER 8

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) on the `master` branch of `ralph-group/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.

Your pull-request will be merged by the PyMeasure maintainers once it meets the coding standards and passes unit tests. You will notice that your pull-request is automatically checked with the unit tests.

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.

```
python setup.py test
```

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 9

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 10

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) 2013-2020 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(Extreme5000, self).__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 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 both of these functions, you can create a number of properties for basic measurements and controls. 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.

10.4 Advanced properties

Many GPIB/SCIP 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.

10.4.1 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.
    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
```

10.4.2 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
```

10.4.3 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. """,
    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.

CHAPTER 11

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

Only Python 3 is used in PyMeasure. This prevents the maintaininace overhead of supporting Python 2.7, which will lose official support in the future.

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.

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 12

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.

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CHAPTER 13

License

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