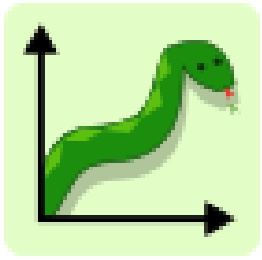
PyMeasure Documentation

Release 0.9.0

PyMeasure Developers

Nov 28, 2021

LEARNING PYMEASURE



PyMeasure

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

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

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

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

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

Information about development is also available:

- *Getting involved*

CHAPTER

ONE

INTRODUCTION

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

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

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

1.1 Instrument ready

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

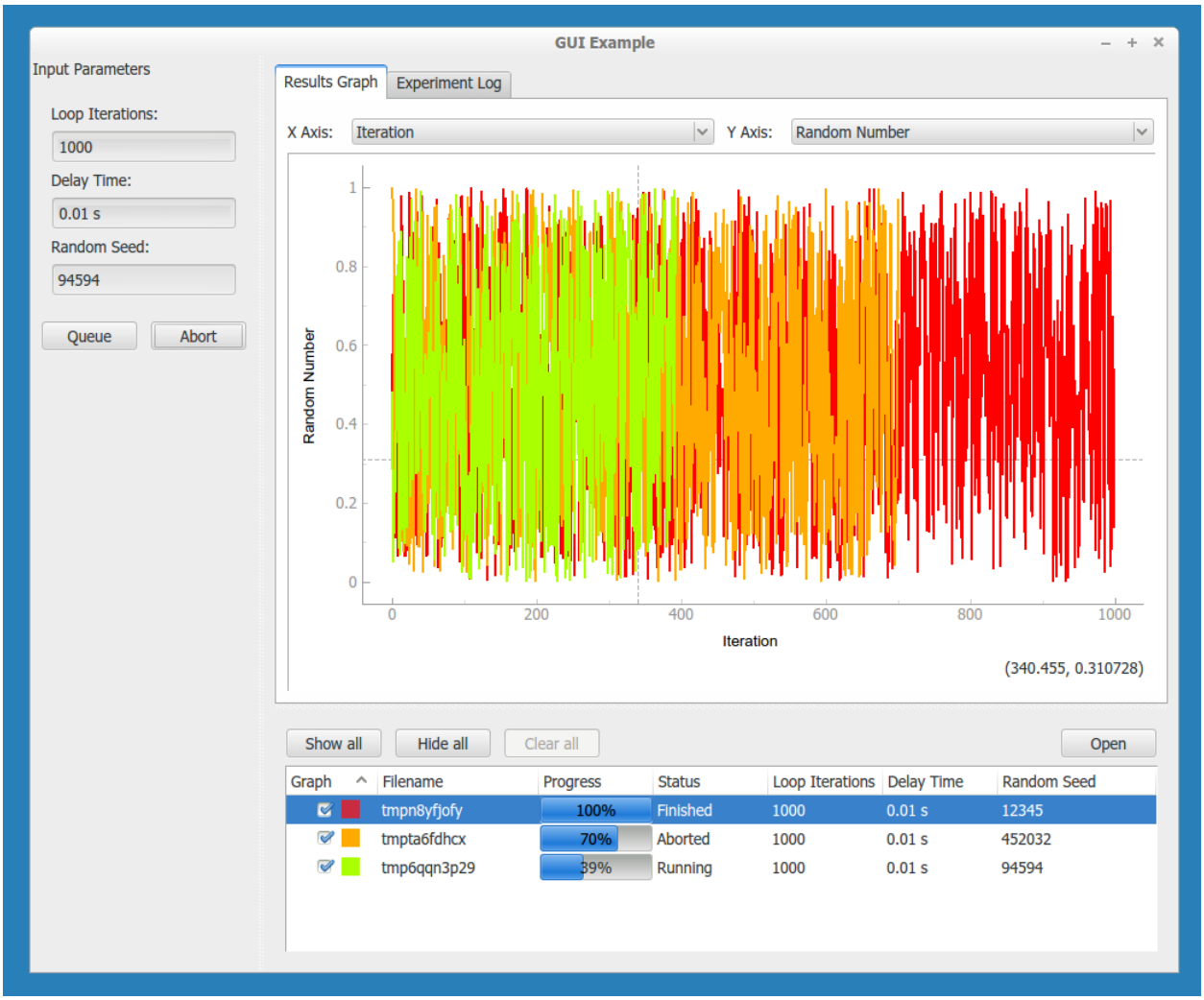
```
from pymeasure.instruments.keithley import Keithley2400
```

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

1.2 Graphical displays

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

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


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

CHAPTER

TWO

QUICK START

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

2.1 Setting up Python

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

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

2.2 Installing PyMeasure

2.2.1 Install with conda

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

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

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

This will install PyMeasure and all the required dependencies.

2.2.2 Install with `pip`

PyMeasure can also be installed with `pip`.

```
pip install pymeasure
```

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

2.2.3 Checking the version

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

```
import pymeasure
pymeasure.__version__
```

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

CHAPTER

THREE

TUTORIALS

The following sections provide instructions for getting started with PyMeasure.

3.1 Connecting to an instrument

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

First import the instrument of interest.

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

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

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

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

```
sourcemeter.id
```

This is equivalent to manually calling the SCPI command.

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

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

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

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

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 *PrologixAdapter*), 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)
```

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

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

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

sourcemeter.shutdown()
```

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

- The progress of the measurement is not transparent
- Input parameters are not associated with the data that is saved
- Data is not plotted during the execution (nor at all in this case)
- Data is only saved upon successful completion, which is otherwise lost
- Canceling a running measurement causes the system to end in a undetermined state
- Exceptions also end the system in an undetermined state

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

3.2.2 Using Procedures

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

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

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

class SimpleProcedure(Procedure):
```

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

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

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

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

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

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

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

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

Next we will show how to run the procedure.

Running Procedures

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

We first construct a Results object for our Procedure.

```
from pymeasure.experiment import Results

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

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

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

```
from pymeasure.experiment import Worker

worker = Worker(results)
```

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

Now we are ready to start the worker.

```
worker.start()
```

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

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

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

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

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):
```

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```
        """ 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}
```

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```
            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)
```

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

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

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

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

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

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

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
```

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

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

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

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

3.3 Using a graphical interface

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

3.3.1 Using the Plotter

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

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

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

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

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

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

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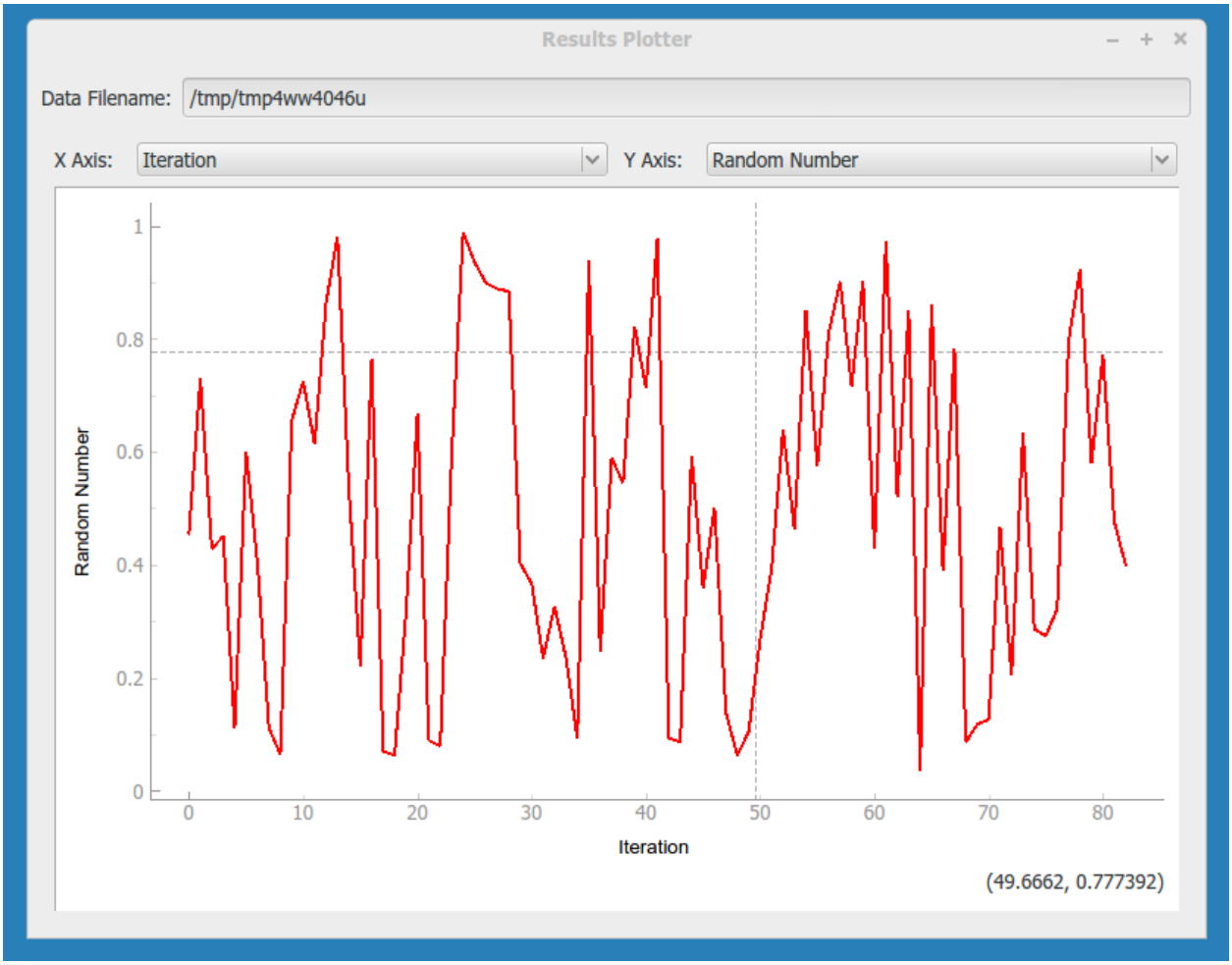
```
    log.info("Finished the measurement")
```

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'
```

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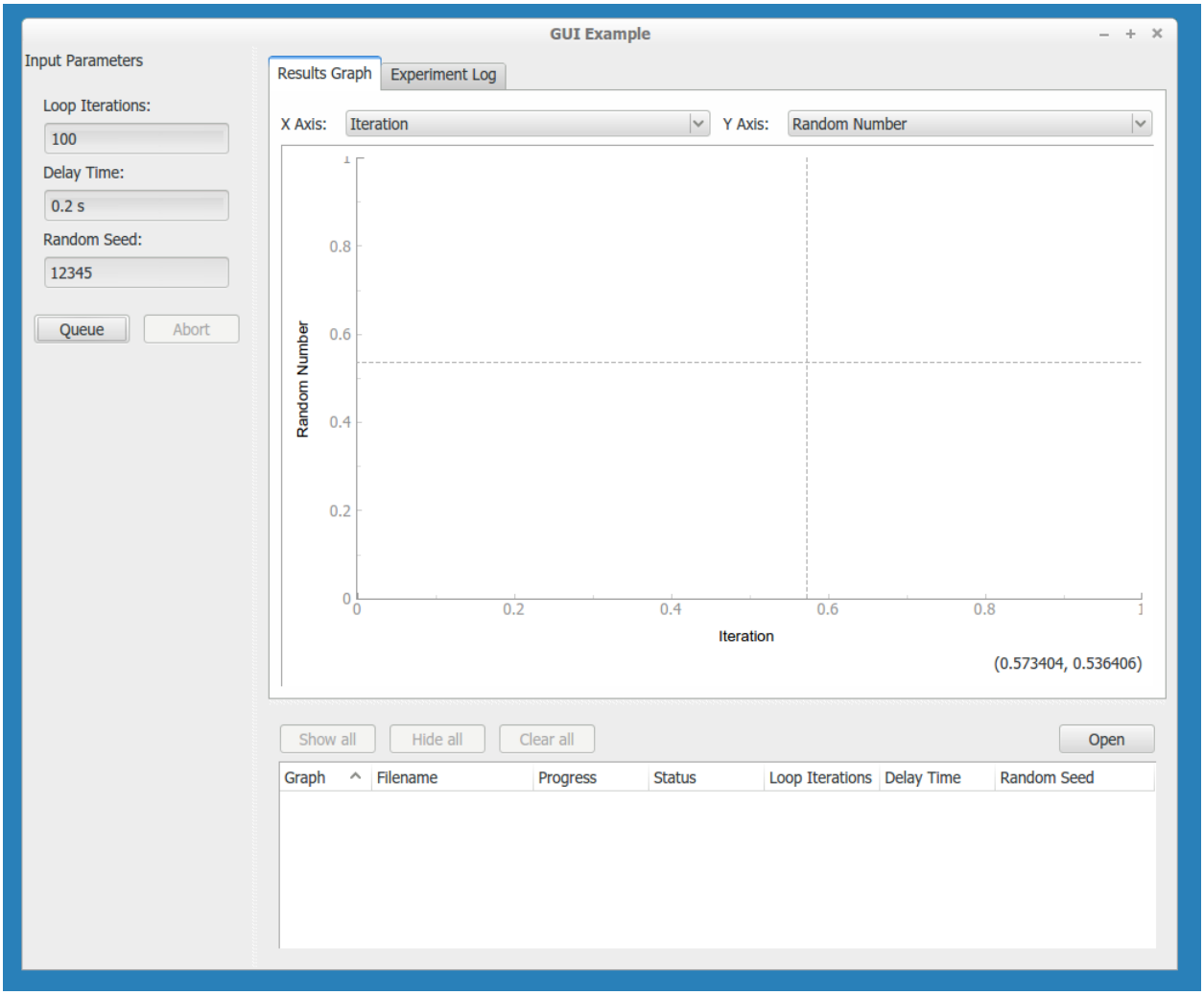
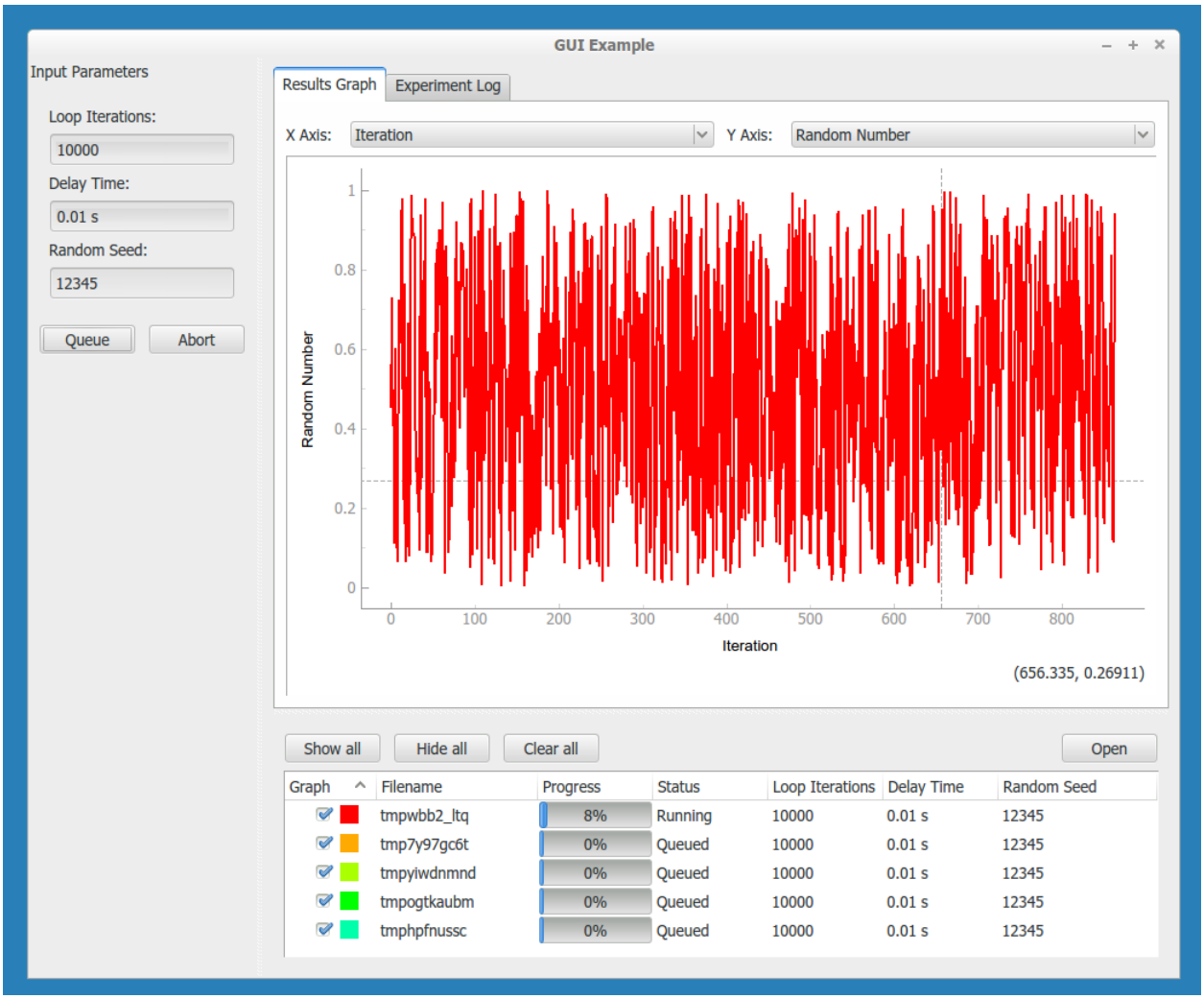
```
        )
        self.setWindowTitle('GUI Example')

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

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

        self.manager.queue(experiment)


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

This results in the following graphical display.

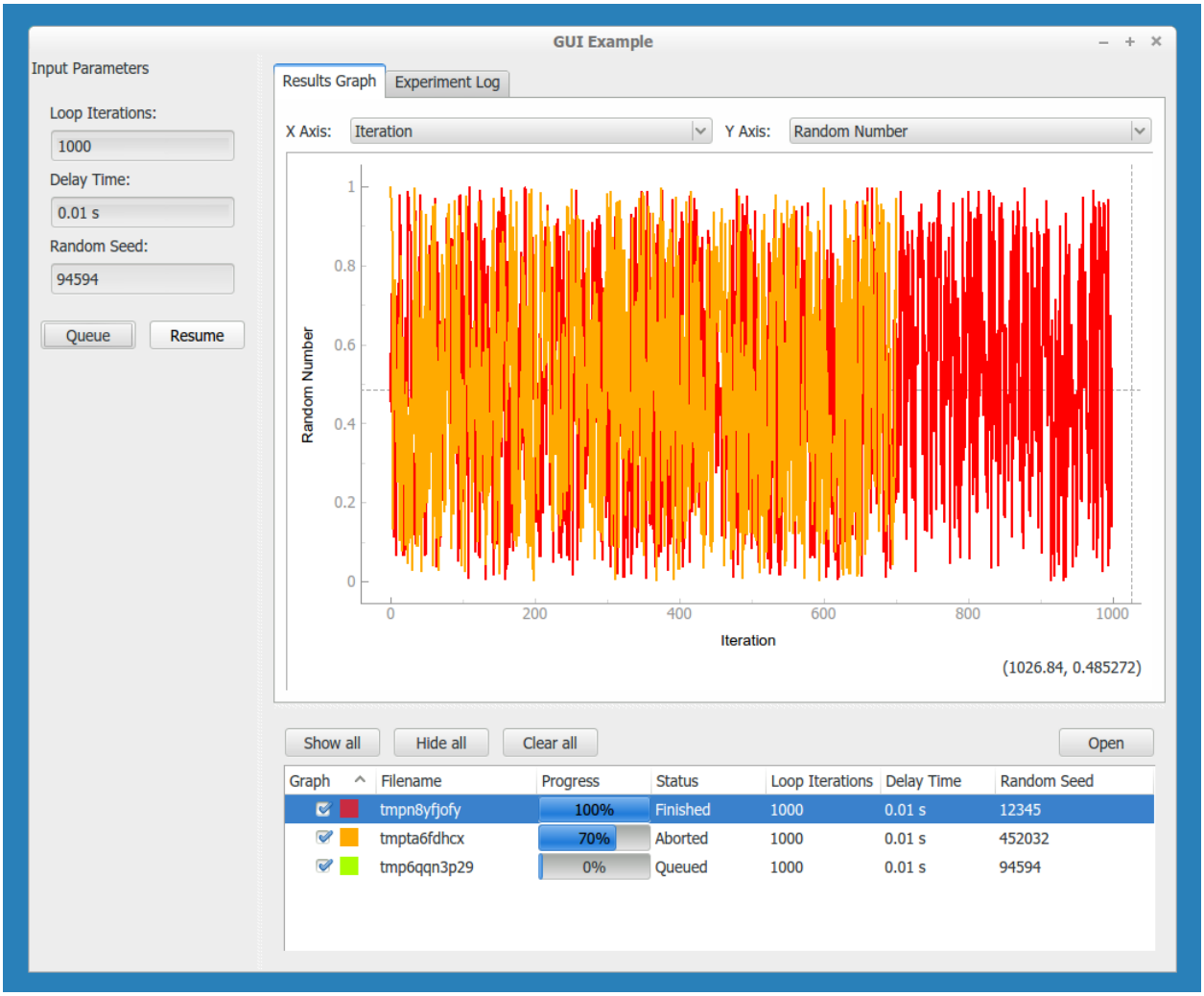


In the code, the MainWindow class is a sub-class of the ManagedWindow class. We override the constructor to provide information about the procedure class and its options. The `inputs` are a list of Parameters class-variable names, which the display will generate graphical fields for. When the list of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

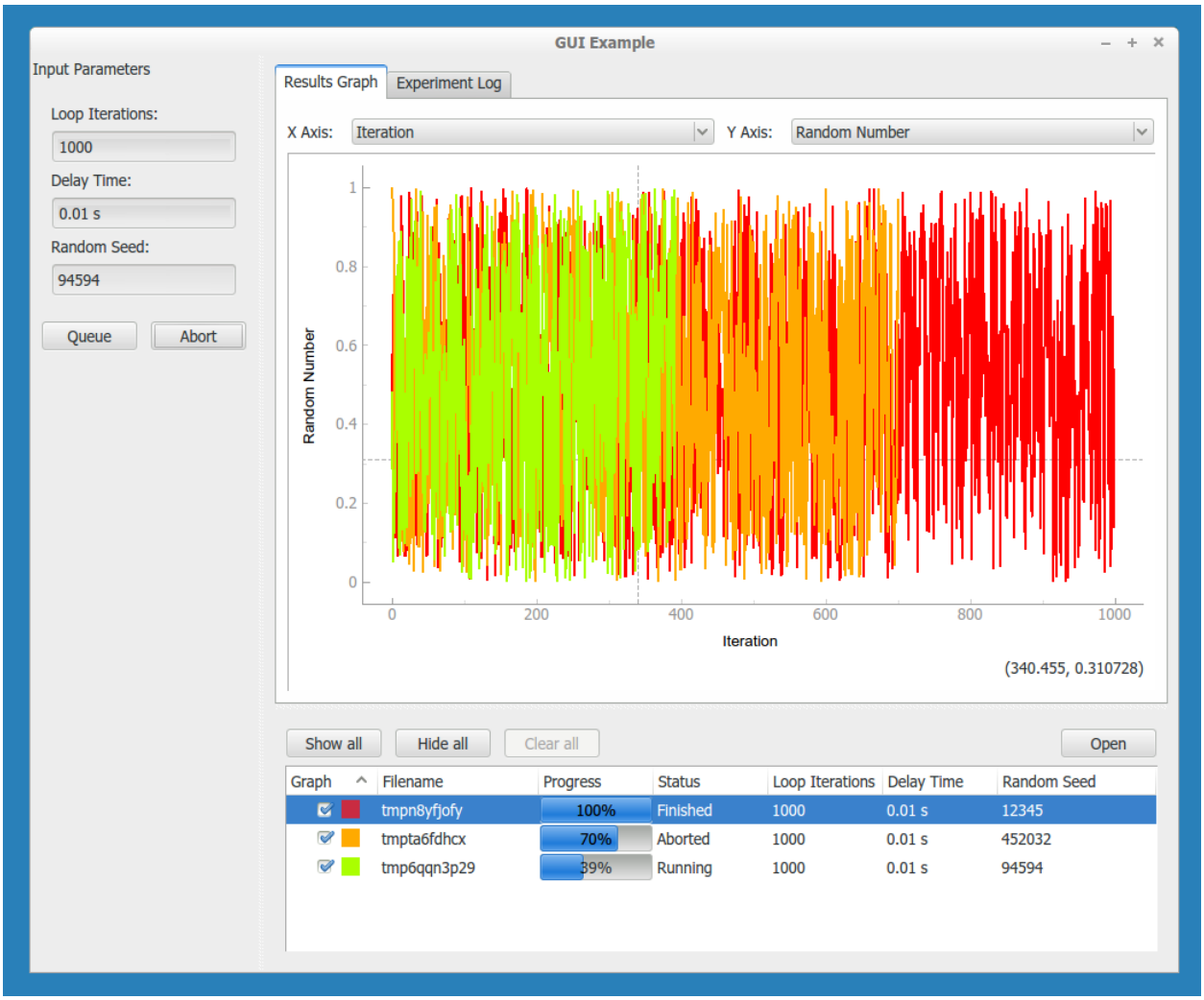
The `queue` method establishes how the Procedure object is constructed. We use the `self.make_procedure` method to create a Procedure based on the graphical input fields. Here we are free to modify the procedure before putting it on the queue. In this context, the Manager uses an Experiment object to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



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



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



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

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

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

3.3.3 Customising the plot options

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

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

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

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

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

3.3.4 Defining your own ManagedWindow's widgets

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

- *LogWidget*
- *PlotWidget*
- *ImageWidget*

3.3.5 Using the sequencer

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

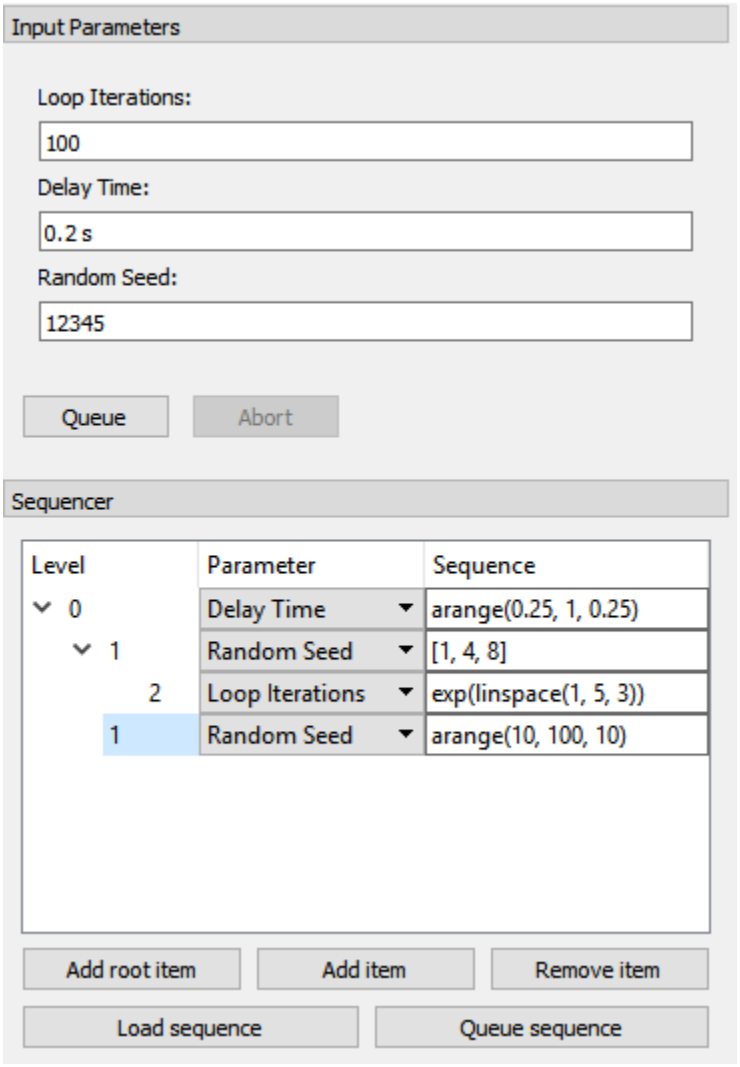
To activate the sequencer, two additional keyword arguments are added to *ManagedWindow*, namely `sequencer` and `sequencer_inputs`. `sequencer` accepts a boolean stating whether or not the sequencer has to be included into the window and `sequencer_inputs` accepts either `None` or a list of the parameter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

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

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

```
class MainWindow(ManagedWindow):

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

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

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

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

        self.manager.queue(experiment)
```

This adds the sequencer underneath the the input panel.



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

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

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

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

Finally, it is possible to write a simple text file to quickly load a pre-defined sequence with the `Load sequence` button, such that the user does not need to write the sequence again each time. In the sequence file each line adds one item

to the sequence tree, starting with a number of dashes (-) to indicate the level of the item (starting with 1 dash for top level), followed by the name of the parameter and the sequence string, both as a python string between parentheses. An example of such a sequence file is given below, resulting in the sequence shown in the figure above.

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

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

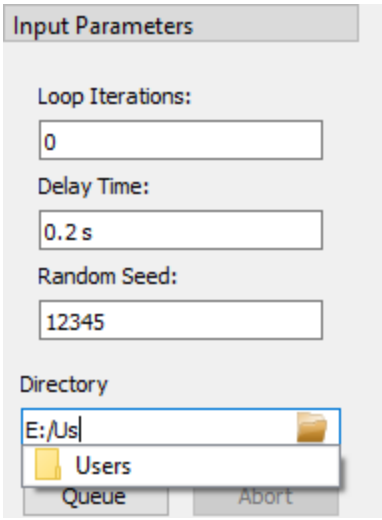
3.3.6 Using the directory input

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

Only the MainWindow needs to be modified in order to use this option (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'],
            x_axis='Iteration',
            y_axis='Random Number',
            directory_input=True,                                   # Added line
        )
        self.setWindowTitle('GUI Example')

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

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

        self.manager.queue(experiment)
```

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



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

3.3.7 Using the estimator widget

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

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

```
class RandomProcedure(Procedure):

    # ...

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

        return self.iterations * self.delay
```

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

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

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

```
class RandomProcedure(Procedure):

    # ...

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

```

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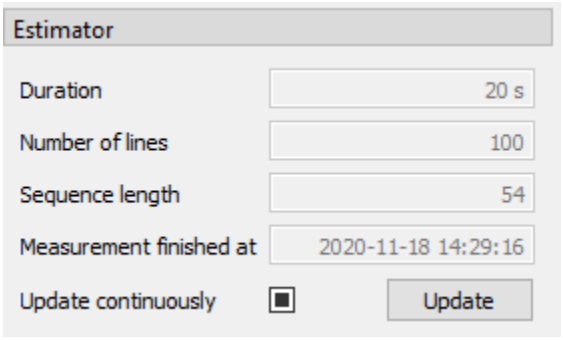
```
        duration = self.iterations * self.delay

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

        return estimates
```

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



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

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

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

3.3.8 Flexible hiding of inputs

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

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

When both the `toggle` and `param` are visible in the `InputsWidget` (via `inputs=['iterations', 'delay', 'seed']` as demonstrated above) one can control whether the input-field of `param` is visible by checking and unchecking the checkbox of `toggle`. By default, the group will be visible if the value of the `group_by` `Parameter` is `True`

(which is only relevant for a `BooleanParameter`), but it is possible to specify other value as conditions using the `group_condition` keyword argument.

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

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

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

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

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

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

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

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

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

CHAPTER

FOUR

PYMEASURE.ADAPTERS

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

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

4.1 Adapter base class

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

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

This class should only be inherited from.

Parameters

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

ask(*command*)

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

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

Returns String ASCII response of the instrument

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

Returns a numpy array from a query for binary data

Parameters

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

Returns NumPy array of values

read()

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

Returns String ASCII response of the instrument.

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

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

Parameters

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

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

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

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

4.2 Fake adapter

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

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

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

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

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

Returns String ASCII response of the instrument

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

Parameters

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

Returns NumPy array of values

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

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

Parameters

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

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

write(*command*)
Writes the command to a buffer, so that it can be read back.

4.3 Serial adapter

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

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

Parameters

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

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

Parameters

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

Returns binary string.

Return type bytes

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

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

Returns String ASCII response of the instrument

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

Parameters

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

Returns NumPy array of values

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

Returns String ASCII response of the instrument.

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

Parameters

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

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

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

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

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

Parameters

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

Returns number of bytes written

4.4 Prologix adapter

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

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

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

Parameters

- **port** – The Serial port name or a serial.Serial object
- **address** – Integer GPIB address of the desired instrument
- **rw_delay** – An optional delay to set between a write and read call for slow to respond instruments.

- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **kwargs** – Key-word arguments if constructing a new serial object

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

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

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

Then reload the udev rules with:

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

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

Parameters

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

Returns binary string.

Return type bytes

ask(*command*)
Ask the Prologix controller, include a forced delay for some instruments.

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

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

Parameters

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

Returns NumPy array of values

gpib(*address*, *rw_delay=None*)
Returns and PrologixAdapter object that references the GPIB address specified, while sharing the Serial connection with other calls of this function

Parameters

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

Returns PrologixAdapter for specific GPIB address

read()
Reads the response of the instrument until timeout

Returns String ASCII response of the instrument

set_defaults()
Sets up the default behavior of the Prologix-GPIB adapter

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

Parameters

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

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

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

Parameters

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

write(*command*)
Writes the command to the GPIB address stored in the *address*

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

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

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

Parameters

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

Returns number of bytes written

4.5 VISA adapter

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

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

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.

- **preprocess_reply** – optional callable used to preprocess strings received from the instrument. The callable returns the processed string.
- **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*, ***kwargs*)
Writes a command to the instrument and returns a list of formatted values from the result. This leverages the *query_ascii_values* method in PyVISA.

Parameters

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

Returns Formatted response of the instrument.

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

Parameters

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

Returns NumPy array of values

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

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

Returns String ASCII response of the instrument.

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

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

Returns String ASCII response of the instrument.

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

Parameters

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

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

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

Parameters

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

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

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

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

Parameters

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

Returns number of bytes written

4.6 VXI-11 adapter

class pymeasure.adapters.**VXI11Adapter**(*host*, *preprocess_reply=None*, ***kwargs*)
Bases: *pymeasure.adapters.adapter.Adapter*

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

Parameters

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

ask(*command*)
Wrapper function for the ask command using the vx11 interface.

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

:returns string containing a response from the device.

ask_raw(*command*)
Wrapper function for the ask_raw command using the vx11 interface.

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

:returns binary string containing the response from the device.

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

Parameters

- **command** – SCPI command to be sent to the instrument
- **header_bytes** – Integer number of bytes to ignore in header

- **dtype** – The NumPy data type to format the values with

Returns NumPy array of values

read()
Wrapper function for the read command using the vx11 interface.

:return string containing a response from the device.

read_raw()
Wrapper function for the read_raw command using the vx11 interface.

:returns binary string containing the response from the device.

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

Parameters

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

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

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

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

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

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

4.7 Telnet adapter

class pymeasure.adapters.**TelnetAdapter**(*host*, *port=0*, *query_delay=0*, *preprocess_reply=None*, ***kwargs*)

Bases: *pymeasure.adapters.adapter.Adapter*

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

Parameters

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

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

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

Returns String ASCII response of the instrument

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

Parameters

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

Returns NumPy array of values

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

Returns String ASCII response of the instrument.

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

Parameters

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

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

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

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

CHAPTER

FIVE

PYMEASURE.EXPERIMENT

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

5.1 Experiment class

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

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

Bases: object

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

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

for a multi-subplot graph:

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

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

Parameters

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

clear_plot()

Clear the figures and plot lists.

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

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

receive(*flags=0*)

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

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

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

stop()
Stop the listener.

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

5.3 Procedure class

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

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

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

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

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

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

gen_measurement()
Create MEASURE and DATA_COLUMNS variables for get_datapoint method.

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

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

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

parameters_are_set()
Returns True if all parameters are set

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

set_parameters(*parameters*, *except_missing=True*)
Sets a dictionary of parameters and raises an exception if additional parameters are present if except_missing is True

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

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

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

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

5.4 Parameter classes

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

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

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

Parameters

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

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

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

Parameters

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

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

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

Parameters

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

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

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

Parameters

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

property choices

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

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

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

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

Parameters

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

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

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

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

Parameters

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

- **group_condition** – The condition for the group_by Parameter that controls the visibility of this parameter, provided as a value or a (lambda)function. If the group_by argument is provided as a list of strings, this argument can be either a single condition or a list of conditions. If the group_by argument is provided as a dict this argument is ignored.

is_set()
Returns True if the Parameter value is set

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

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

Parameters

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

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

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

Parameters

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

5.5 Worker class

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

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

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

handle_abort()

handle_error()

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

Parameters **timeout** – Timeout duration in seconds

run()
Method representing the thread's activity.

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

shutdown()

update_status(*status*)

5.6 Results class

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

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

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

Returns a string

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

Variables

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

Parameters

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

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

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

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

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

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

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

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

pymeasure.experiment.results.**replace_placeholders**(*string*, *procedure*, *date_format='%Y-%m-%d'*, *time_format='%H:%M:%S'*)

Replace placeholders in string with values from procedure parameters.

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

Parameters

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

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

Returns a unique filename based on the directory and prefix

CHAPTER

SIX

PYMEASURE.DISPLAY

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

6.1 Browser classes

class pymeasure.display.browser.**Browser**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

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

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

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

class pymeasure.display.browser.**BrowserItem**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

Represent a row in the *Browser* tree widget

6.2 Curves classes

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

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**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtCore.

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

mouseMoved(*event=None*)
Updates the mouse position upon mouse movement

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

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

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_data()
Updates the data by polling the results

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

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

Checkbox for boolean values, connected to a BooleanParameter.

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

Parameters **parameter** – parameter to connect.

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

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

See also:

Class *ScientificInput* For inputs in scientific notation.

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

Parameters **parameter** – parameter to connect.

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

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

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

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

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

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

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

Parameters **parameter** – parameter to connect.

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

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

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

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

Parameters **parameter** – parameter to connect.

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

Dropdown for list values, connected to a ListParameter.

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

Parameters **parameter** – parameter to connect.

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

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

See also:

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

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

Parameters **parameter** – parameter to connect.

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

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

6.4 Listeners classes

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

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

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

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

6.5 Log classes

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

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

record

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

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

6.6 Manager classes

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

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

Parameters

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

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

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

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

next()
Returns the next experiment on the queue

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

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

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

clear()
Remove all Experiments

is_running()
Returns True if a procedure is currently running

load(*experiment*)
Load a previously executed Experiment

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

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

remove(*experiment*)
Removes an Experiment

resume()
Resume processing of the queue.

6.7 Plotter class

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

Plotter dynamically plots data from a file through the Results object 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**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtCore.

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: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

class pymeasure.display.widgets.**DirectoryLineEdit**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

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

class pymeasure.display.widgets.**EstimatorThread**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtCore.

class pymeasure.display.widgets.**EstimatorWidget**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

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

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

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

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

display_estimates(*estimates*)
Method that updates the shown estimates for the given set of estimates.

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

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

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

class pymeasure.display.widgets.**ImageFrame**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

Extends PlotFrame to plot also axis Z using colors

ResultsClass
alias of *pymeasure.display.curves.ResultsImage*

class pymeasure.display.widgets.**ImageWidget**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.widgets.TabWidget*, pyqtgraph.Qt.QtGui.

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

load(*curve*)
Add curve to widget

new_curve(*results*, *color=pyqtgraph.intColor*, ***kwargs*)
Creates a new image

remove(*curve*)
Remove curve from widget

class pymeasure.display.widgets.**InputsWidget**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

get_procedure()
Returns the current procedure

class pymeasure.display.widgets.**LogWidget**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.widgets.TabWidget*, pyqtgraph.Qt.QtGui.

Widget to display logging information in GUI

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

class pymeasure.display.widgets.**PlotFrame**(**args: Any*, ***kwargs: Any*)
Bases: pyqtgraph.Qt.QtGui.

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

ResultsClass
alias of *pymeasure.display.curves.ResultsCurve*

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

class pymeasure.display.widgets.**PlotWidget**(**args: Any*, ***kwargs: Any*)
Bases: *pymeasure.display.widgets.TabWidget*, pyqtgraph.Qt.QtGui.

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

load(*curve*)
Add curve to widget

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

remove(*curve*)
Remove curve from widget

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

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

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

Raised when the evaluation of a sequence string goes wrong.

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

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

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

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

Parameters

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

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

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

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

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

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

Utility class to define default implementation for some basic methods.

When defining a widget to be used in subclasses of ManagedWindowBase, users should inherit from this class and provide the specialized implementation of these method's

load(*curve*)
Add curve to widget

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

remove(*curve*)
Remove curve from widget

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

6.11 Windows classes

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

Display experiment output with an ImageWidget class.

Parameters

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

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

Display experiment output with an PlotWidget class.

See also:

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

Parameters

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

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

Base class for GUI experiment management .

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

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

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

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

- *LogWidget*
- *PlotWidget*
- *ImageWidget*

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

Examples of ready to use classes inherited from ManagedWindowBase are:

- *ManagedWindow*
- *ManagedImageWindow*

See also:

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

Parameters for `__init__` constructor.

Parameters

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

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

queue(*procedure=None*)
Abstract method, which must be overridden by the child class.

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

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

For example:

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

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

    self.manager.queue(experiment)
```

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

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

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

See also:

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

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

CHAPTER

SEVEN

PYMEASURE.INSTRUMENTS

This section contains documentation on the instrument classes.

7.1 Instrument classes

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

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()

Read all errors from the instrument.

Returns list of error entries

clear()

Clears the instrument status byte

property complete

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

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

property id
Requests and returns the identification of the instrument.

static measurement(*get_command*, *docs*, *values=()*, *map_values=None*, *get_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_get_errors=False*, ***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

property options
Requests and returns the device options installed.

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

reset()
Resets the instrument.

static setting(*set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *set_process=<function Instrument.<lambda>>*, *check_set_errors=False*, ***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

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

values(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

write(*command*)
Writes the command to the instrument through the adapter.

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

class pymeasure.instruments.**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.

property time
Get elapsed time

property voltage
Get the voltage.

property 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.

property center_frequency
Center Frequency in Hz

property id
Reads the instrument identification

property span_frequency
Span Frequency in Hz

property start_frequency
Starting frequency in Hz

property stop_frequency
Stoping frequency in Hz

property trace_1
Reads the Data array from trace 1 after formatting

7.6 Agilent

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

7.6.1 Agilent 8257D Signal Generator

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

Bases: *pymeasure.instruments.instrument.Instrument*

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

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

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

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

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

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

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

Parameters

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

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

Parameters

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

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

Parameters

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

config_step_sweep()
Configures a step sweep through frequency

disable()
Disables the output of the signal.

disable_amplitude_modulation()
Disables amplitude modulation of the output signal.

disable_low_freq_out()
Disables low frequency output

disable_modulation()
Disables the signal modulation.

disable_pulse_modulation()
Disables pulse modulation of the output signal.

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

enable()
Enables the output of the signal.

enable_amplitude_modulation()
Enables amplitude modulation of the output signal.

enable_low_freq_out()
Enables low frequency output

enable_pulse_modulation()
Enables pulse modulation of the output signal.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

start_step_sweep()
Starts a step sweep.

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

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

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

stop_step_sweep()
Stops a step sweep.

7.6.2 Agilent 8722ES Vector Network Analyzer

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

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

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

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

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

property data_complex
Returns the complex power from the last scan

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

property data_magnitude
Returns the absolute magnitude values from the last scan

property data_phase
Returns the phase in degrees from the last scan

disable_averaging()
Disables averaging

enable_averaging()
Enables averaging

property frequencies
Returns a list of frequencies from the last scan

is_averaging()
Returns True if averaging is enabled

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

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

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

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

scan_continuous()
Initiates a continuous scan

property scan_points
Gets the number of scan points

scan_single()
Initiates a single scan

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

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

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

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

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

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

7.6.3 Agilent E4408B Spectrum Analyzer

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

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

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

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

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

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

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

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

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

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

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

7.6.4 Agilent E4980 LCR Meter

class pymeasure.instruments.agilent.**AgilentE4980**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents LCR meter E4980A/AL

property ac_current
AC current level, in Amps

property ac_voltage
AC voltage level, in Volts

aperture(*time=None*, *averages=1*)
Set and get aperture.

Parameters

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

freq_sweep(*freq_list*, *return_freq=False*)
Run frequency list sweep using sequential trigger.

Parameters

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

Returns values as configured with *mode*

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

property impedance
Measured data A and B, according to *mode*

property mode
Select quantities to be measured:

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

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

property trigger_source

Select trigger source; accept the values:

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

7.6.5 Agilent 34410A Multimeter

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

Bases: *pymeasure.instruments.instrument.Instrument*

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

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

property current_ac
AC current, in Amps

property current_dc
DC current, in Amps

property resistance
Resistance, in Ohms

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

property voltage_ac
AC voltage, in Volts

property voltage_dc
DC voltage, in Volts

7.6.6 HP/Agilent/Keysight 34450A Digital Multimeter

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

Bases: *pymeasure.instruments.instrument.Instrument*

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

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

beep()
Sounds a system beep.

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

property capacitance_auto_range
A boolean property that toggles auto ranging for capacitance.

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

configure_capacitance(*capacitance_range='AUTO'*)
Configures the instrument to measure capacitance.

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

configure_continuity()
Configures the instrument to measure continuity.

configure_current(*current_range='AUTO'*, *ac=False*, *resolution='DEF'*)
Configures the instrument to measure current.

Parameters

- **current_range** – A current in Amps to set the current range. DC values can be 100E-6, 1E-3, 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", "DEF" (100 mA), or "AUTO". AC values can be 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", "DEF" (100 mA), or "AUTO".
- **ac** – False for DC current, and True for AC current
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

configure_diode()
Configures the instrument to measure diode voltage.

configure_frequency(*measured_from='voltage_ac'*, *measured_from_range='AUTO'*, *aperture='DEF'*)
Configures the instrument to measure frequency.

Parameters

- **measured_from** – "voltage_ac" or "current_ac"

- **measured_from_range** – range of measured_from. AC voltage can have ranges 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO". AC current can have ranges 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", "DEF" (100 mA), or "AUTO".
- **aperture** – Aperture time in Seconds, can be 100 ms, 1 s, as well as "MIN", "MAX", or "DEF" (1 s).

configure_resistance(*resistance_range='AUTO'*, *wires=2*, *resolution='DEF'*)
Configures the instrument to measure resistance.

Parameters

- **resistance_range** – A resistance in Ohms to set the resistance range, can be 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", "DEF" (1E3), or "AUTO".
- **wires** – Number of wires used for measurement, can be 2 or 4.
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

configure_temperature()
Configures the instrument to measure temperature.

configure_voltage(*voltage_range='AUTO'*, *ac=False*, *resolution='DEF'*)
Configures the instrument to measure voltage.

Parameters

- **voltage_range** – A voltage in Volts to set the voltage range. DC values can be 100E-3, 1, 10, 100, 1000, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO". AC values can be 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", "DEF" (10 V), or "AUTO".
- **ac** – False for DC voltage, True for AC voltage
- **resolution** – Desired resolution, can be 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

property continuity
Reads a continuity measurement in Ohms, based on the active mode.

property current
Reads a DC current measurement in Amps, based on the active mode.

property current_ac
Reads an AC current measurement in Amps, based on the active mode.

property current_ac_auto_range
A boolean property that toggles auto ranging for AC current.

property current_ac_range
A property that controls the AC current range in Amps, which can take values 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

property current_ac_resolution
An property that controls the resolution in the AC current readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

property current_auto_range
A boolean property that toggles auto ranging for DC current.

property current_range
A property that controls the DC current range in Amps, which can take values 100E-6, 1E-3, 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

property current_resolution
A property that controls the resolution in the DC current readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", and "DEF" (3.00E-5).

property diode
Reads a diode measurement in Volts, based on the active `mode`.

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

property frequency_aperture
A property that controls the frequency aperture in seconds, which sets the integration period and measurement speed. Takes values 100 ms, 1 s, as well as "MIN", "MAX", or "DEF" (1 s).

property frequency_current_auto_range
A boolean property that toggles auto ranging for AC current in frequency measurements.

property frequency_current_range
A property that controls the current range in Amps for frequency on AC current measurements, which can take values 10E-3, 100E-3, 1, 10, as well as "MIN", "MAX", or "DEF" (100 mA). Auto-range is disabled when this property is set.

property frequency_voltage_auto_range
A boolean property that toggles auto ranging for AC voltage in frequency measurements.

property frequency_voltage_range
A property that controls the voltage range in Volts for frequency on AC voltage measurements, which can take values 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

property resistance
Reads a resistance measurement in Ohms for 2-wire configuration, based on the active `mode`.

property resistance_4w
Reads a resistance measurement in Ohms for 4-wire configuration, based on the active `mode`.

property resistance_4w_auto_range
A boolean property that toggles auto ranging for 4-wire resistance.

property resistance_4w_range
A property that controls the 4-wire resistance range in Ohms, which can take values 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", or "DEF" (1E3). Auto-range is disabled when this property is set.

property resistance_4w_resolution
A property that controls the resolution in the 4-wire resistance readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

property resistance_auto_range
A boolean property that toggles auto ranging for 2-wire resistance.

property resistance_range
A property that controls the 2-wire resistance range in Ohms, which can take values 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, as well as "MIN", "MAX", or "DEF" (1E3). Auto-range is disabled when this property is set.

property resistance_resolution
A property that controls the resolution in the 2-wire resistance readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

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

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

property voltage_ac
Reads an AC voltage measurement in Volts, based on the active `mode`.

property voltage_ac_auto_range
A boolean property that toggles auto ranging for AC voltage.

property voltage_ac_range
A property that controls the AC voltage range in Volts, which can take values 100E-3, 1, 10, 100, 750, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

property voltage_ac_resolution
A property that controls the resolution in the AC voltage readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

property voltage_auto_range
A boolean property that toggles auto ranging for DC voltage.

property voltage_range
A property that controls the DC voltage range in Volts, which can take values 100E-3, 1, 10, 100, 1000, as well as "MIN", "MAX", or "DEF" (10 V). Auto-range is disabled when this property is set.

property voltage_resolution
A property that controls the resolution in the DC voltage readings, which can take values 3.00E-5, 2.00E-5, 1.50E-6 (5 1/2 digits), as well as "MIN", "MAX", or "DEF" (1.50E-6).

7.6.7 Agilent 4155/4156 Semiconductor Parameter Analyzer

class pymeasure.instruments.agilent.agilent4156.**Agilent4156**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 4155/4156 Semiconductor Parameter Analyzer and provides a high-level interface for taking current-voltage (I-V) measurements.

```
from pymeasure.instruments.agilent import Agilent4156

# explicitly define r/w terminations; set sufficiently large timeout or None.
smu = Agilent4156("GPIB0::25", read_termination = '\n', write_termination = '\n',␣
↪timeout=None)

# reset the instrument
smu.reset()

# define configuration file for instrument and load config
smu.configure("configuration_file.json")

# save data variables, some or all of which are defined in the json config file.
smu.save(['VC', 'IC', 'VB', 'IB'])
```

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```
# take measurements
status = smu.measure()

# measured data is a pandas dataframe and can be exported to csv.
data = smu.get_data(path='./t1.csv')
```

The JSON file is an ascii text configuration file that defines the settings of each channel on the instrument. The JSON file is used to configure the instrument using the convenience function *configure()* as shown in the example above. For example, the instrument setup for a bipolar transistor measurement is shown below.

```
{
       "SMU1": {
           "voltage_name" : "VC",
           "current_name" : "IC",
           "channel_function" : "VAR1",
           "channel_mode" : "V",
           "series_resistance" : "0OHM"
       },

       "SMU2": {
           "voltage_name" : "VB",
           "current_name" : "IB",
           "channel_function" : "VAR2",
           "channel_mode" : "I",
           "series_resistance" : "0OHM"
       },

       "SMU3": {
           "voltage_name" : "VE",
           "current_name" : "IE",
           "channel_function" : "CONS",
           "channel_mode" : "V",
           "constant_value" : 0,
           "compliance" : 0.1
       },

        "SMU4": {
           "voltage_name" : "VS",
           "current_name" : "IS",
           "channel_function" : "CONS",
           "channel_mode" : "V",
           "constant_value" : 0,
           "compliance" : 0.1
       },

       "VAR1": {
           "start" : 1,
           "stop" : 2,
           "step" : 0.1,
           "spacing" : "LINEAR",
           "compliance" : 0.1
```

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```
        },

        "VAR2": {
            "start" : 0,
            "step" : 10e-6,
            "points" : 3,
            "compliance" : 2

        }
    }
```

property analyzer_mode

A string property that controls the instrument operating mode.

- Values: SWEEP, SAMPLING

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

configure(*config_file*)

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')
```

property 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
```

property delay_time

A floating point property that measurement delay time in seconds, which can take the values from 0 to 65s in 0.1s steps.

```
instr.delay_time = 1 # delay time of 1-sec
```

disable_all()

Disables all channels in the instrument.

```
instr.disable_all()
```

get_data(*path=None*)

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')
```

property hold_time
A floating point property that measurement hold time in seconds, which can take the values from 0 to 655s in 1s steps.

```
instr.hold_time = 2 # hold time of 2-secs.
```

property integration_time
A string property that controls the integration time.

- Values: SHORT, MEDIUM, LONG

```
instr.integration_time = "MEDIUM"
```

measure(*period='INF'*, *points=100*)
Performs a single measurement and waits for completion in sweep mode. In sampling mode, the measurement period and number of points can be specified.

Parameters

- **period** – Period of sampling measurement from 6E-6 to 1E11 seconds. Default setting is INF.
- **points** – Number of samples to be measured, from 1 to 10001. Default setting is 100.

save(*trace_list*)
Save the voltage or current in the instrument display list

Parameters **trace_list** – A list of channel variables whose measured data should be saved. A maximum of 8 variables are allowed. If only one variable is being saved, a string can be specified.

```
instr.save(['IC', 'IB', 'VC', 'VB']) #for list of variables
instr.save('IC')    #for single variable
```

save_var(*trace_list*)
Save the voltage or current in the instrument variable list. This is useful if one or two more variables need to be saved in addition to the 8 variables allowed by *save()*.

Parameters **trace_list** – A list of channel variables whose measured data should be saved. A maximum of 2 variables are allowed. If only one variable is being saved, a string can be specified.

```
instr.save_var(['VA', 'VB'])
```

stop()
Stops the ongoing measurement

```
instr.stop()
```

class pymeasure.instruments.agilent.agilent4156.**SMU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

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

- Values: VAR1, VAR2, VARD or CONS.

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

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

- Values: `V`, `I` or `COMM`

VPULSE AND IPULSE are not yet supported.

```
instr.smu1.channel_mode = "V"
```

property compliance
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
```

property 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
```

property current_name
Define the current name of the channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.smu1.current_name = "Ibase"
```

property disable
This command deletes the settings of SMU<n>.

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

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

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

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

property voltage_name
Define the voltage name of the channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.smu1.voltage_name = "Vbase"
```

class pymeasure.instruments.agilent.agilent4156.**VAR1**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.agilent.agilent4156.VARX*

Class to handle all the specific definitions needed for VAR1. Most common methods are inherited from base class.

property spacing
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.

property 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.

property compliance
This command sets the sweep COMPLIANCE value of VARD.

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

property 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
```

property 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

property compliance
Sets the sweep COMPLIANCE value.

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

property start
Sets the sweep START value.

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

property step
Sets the sweep STEP value.

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

property stop
Sets the sweep STOP value.

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

class pymeasure.instruments.agilent.agilent4156.**VMU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

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

- Values: `V`, `DVOL`

property disable
This command disables the settings of VMU<n>.

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

property voltage_name
Define the voltage name of the VMU channel.

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.vmu1.voltage_name = "Vanode"
```

class pymeasure.instruments.agilent.agilent4156.**VSU**(*resourceName*, *channel*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

property channel_function
A string property that controls the VSU channel function.

- Value: `VAR1`, `VAR2`, `VARD` or `CONS`.

property channel_mode
Get channel mode of VSU<n>.

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

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

property disable
This command deletes the settings of VSU<n>.

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

property voltage_name
Define the voltage name of the VSU channel

If input is greater than 6 characters long or starts with a number, the name is autocorrected and prepended with 'a'. Event is logged.

```
instr.vsu1.voltage_name = "Ve"
```

7.6.8 Agilent 33220A Arbitrary Waveform Generator

class pymeasure.instruments.agilent.**Agilent33220A**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 33220A Arbitrary Waveform Generator.

```
# Default channel for the Agilent 33220A
wfg = Agilent33220A("GPIB::10")

wfg.shape = "SINUSOID"          # Sets a sine waveform
wfg.frequency = 4.7e3           # Sets the frequency to 4.7 kHz
wfg.amplitude = 1               # Set amplitude of 1 V
wfg.offset = 0                  # Set the amplitude to 0 V

wfg.burst_state = True          # Enable burst mode
wfg.burst_ncycles = 10          # A burst will consist of 10 cycles
wfg.burst_mode = "TRIGGERED"    # A burst will be applied on a trigger
wfg.trigger_source = "BUS"      # A burst will be triggered on TRG*

wfg.output = True               # Enable output of waveform generator
wfg.trigger()                   # Trigger a burst
wfg.wait_for_trigger()          # Wait until the triggering is finished
wfg.beep()                      # "beep"

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

property amplitude

A floating point property that controls the voltage amplitude of the output waveform in V, from 10e-3 V to 10 V. Can be set.

property amplitude_unit

A string property that controls the units of the amplitude. Valid values are Vpp (default), Vrms, and dBm. Can be set.

beep()

Causes a system beep.

property beeper_state

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

property burst_mode

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

property burst_ncycles

An integer property that sets the number of cycles to be output when a burst is triggered. Valid values are 1 to 50000. This can be set.

property burst_state

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

property frequency

A floating point property that controls the frequency of the output waveform in Hz, from 1e-6 (1 uHz) to 20e+6 (20 MHz), depending on the specified function. Can be set.

property offset

A floating point property that controls the voltage offset of the output waveform in V, from 0 V to 4.995 V,

depending on the set voltage amplitude (maximum offset = (10 - voltage) / 2). Can be set.

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

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

property pulse_hold
A string property that controls if either the pulse width or the duty cycle is retained when changing the period or frequency of the waveform. Can be set to: WIDT<H> or DCYC<LE>.

property pulse_period
A floating point property that controls the period of a pulse waveform function in seconds, ranging from 200 ns to 2000 s. Can be set and overwrites the frequency for *all* waveforms. If the period is shorter than the pulse width + the edge time, the edge time and pulse width will be adjusted accordingly.

property pulse_transition
A floating point property that controls the the edge time in seconds for both the rising and falling edges. It is defined as the time between 0.1 and 0.9 of the threshold. Valid values are between 5 ns to 100 ns. The transition time has to be smaller than 0.625 * the pulse width. Can be set.

property pulse_width
A floating point property that controls the width of a pulse waveform function in seconds, ranging from 20 ns to 2000 s, within a set of restrictions depending on the period. Can be set.

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

property remote_local_state
A string property that controls the remote/local state of the function generator. Valid values are: LOC<AL>, REM<OTE>, RWL<OCK>. This setting can only be set.

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

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

trigger()
Send a trigger signal to the function generator.

property trigger_source
A string property that controls the trigger source. Valid values are: IMM<EDIATE> (internal), EXT<ERNAL> (rear input), BUS (via trigger command). This setting can be set.

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

property voltage_high
A floating point property that controls the upper voltage of the output waveform in V, from -4.990 V to 5 V (must be higher than low voltage). Can be set.

property voltage_low
A floating point property that controls the lower voltage of the output waveform in V, from -5 V to 4.990 V (must be lower than high voltage). Can be set.

wait_for_trigger(*timeout=3600*, *should_stop=<function Agilent33220A.<lambda>>*)
Wait until the triggering has finished or timeout is reached.

Parameters

- **timeout** – The maximum time the waiting is allowed to take. If timeout is exceeded, a TimeoutError is raised. If timeout is set to zero, no timeout will be used.
- **should_stop** – Optional function (returning a bool) to allow the waiting to be stopped before its end.

7.6.9 Agilent 33500 Function/Arbitrary Waveform Generator Family

class pymeasure.instruments.agilent.**Agilent33500**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent 33500 Function/Arbitrary Waveform Generator family. Individual devices are represented by subclasses.

```
generator = Agilent33500("GPIB::1")

generator.shape = 'SIN'                 # Sets the output signal shape to sine
generator.frequency = 1e3               # Sets the output frequency to 1 kHz
generator.amplitude = 5                 # Sets the output amplitude to 5 Vpp
generator.output = 'on'                 # Enables the output

generator.shape = 'ARB'                 # Set shape to arbitrary
generator.arb_srate = 1e6               # Set sample rate to 1MSa/s

generator.data_volatile_clear()         # Clear volatile internal memory
generator.data_arb(                     # Send data points of arbitrary waveform
    'test',
    range(-10000, 10000, +20),          # In this case a simple ramp
    data_format='DAC'                   # Data format is set to 'DAC'
)
generator.arb_file = 'test'             # Select the transmitted waveform 'test'
```

property amplitude

A floating point property that controls the voltage amplitude of the output waveform in V, from 10e-3 V to 10 V. Depends on the output impedance. Can be set.

property amplitude_unit

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

property arb_advance

A string property that selects how the device advances from data point to data point. Can be set to 'TRIG<GER>' or 'SRAT<E>' (default).

property arb_file

A string property that selects the arbitrary signal from the volatile memory of the device. String has to match an existing arb signal in volatile memore (set by data_arb()). Can be set.

property arb_filter

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

property arb_srate

An floating point property that sets the sample rate of the currently selected arbitrary signal. Valid values are 1 µSa/s to 250 MSa/s (maximum range, can be lower depending on your device). This can be set.

beep()
Causes a system beep.

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

property burst_ncycles
An integer property that sets the number of cycles to be output when a burst is triggered. Valid values are 1 to 100000. This can be set.

property burst_period
A floating point property that controls the period of subsequent bursts. Has to follow the equation burst_period > (burst_ncycles / frequency) + 1 µs. Valid values are 1 µs to 8000 s. Can be set.

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

clear_display()
Removes a text message from the display.

data_arb(*arb_name*, *data_points*, *data_format='DAC'*)
Uploads an arbitrary trace into the volatile memory of the device. The data_points can be given as comma separated 16 bit DAC values (ranging from -32767 to +32767), as comma separated floating point values (ranging from -1.0 to +1.0) or as a binary data stream. Check the manual for more information. The storage depends on the device type and ranges from 8 Sa to 16 MSa (maximum). TODO: *Binary is not yet implemented*

Parameters

- **arb_name** – The name of the trace in the volatile memory. This is used to access the trace.
- **data_points** – Individual points of the trace. The format depends on the format parameter.

  format = 'DAC' (default): Accepts list of integer values ranging from -32767 to +32767. Minimum of 8 a maximum of 65536 points.

  format = 'float': Accepts list of floating point values ranging from -1.0 to +1.0. Minimum of 8 a maximum of 65536 points.

  format = 'binary': Accepts a binary stream of 8 bit data.
- **data_format** – Defines the format of data_points. Can be 'DAC' (default), 'float' or 'binary'. See documentation on parameter data_points above.

data_volatile_clear()
Clear all arbitrary signals from the volatile memory. This should be done if the same name is used continuously to load different arbitrary signals into the memory, since an error will occur if a trace is loaded which already exists in the memory.

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

property ext_trig_out
A boolean property that controls whether the trigger out signal is active (True) or not (False). This signal is output from the Ext Trig connector on the rear panel in Burst and Wobbel mode. Can be set.

property frequency
A floating point property that controls the frequency of the output waveform in Hz, from 1 uHz to 120 MHz (maximum range, can be lower depending on your device), depending on the specified function. Can be set.

property id
Reads the instrument identification

property offset
A floating point property that controls the voltage offset of the output waveform in V, from 0 V to 4.995 V, depending on the set voltage amplitude (maximum offset = (Vmax - voltage) / 2). Can be set.

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

property output_load
Sets the expected load resistance (should be the load impedance connected to the output. The output impedance is always 50 Ohm, this setting can be used to correct the displayed voltage for loads unmatched to 50 Ohm. Valid values are between 1 and 10 kOhm or INF for high impedance. No validator is used since both numeric and string inputs are accepted, thus a value outside the range will not return an error. Can be set.

property phase
A floating point property that controls the phase of the output waveform in degrees, from -360 degrees to 360 degrees. Not available for arbitrary waveforms or noise. Can be set.

property pulse_dutycycle
A floating point property that controls the duty cycle of a pulse waveform function in percent, from 0% to 100%. Can be set.

property pulse_hold
A string property that controls if either the pulse width or the duty cycle is retained when changing the period or frequency of the waveform. Can be set to: WIDT<H> or DCYC<LE>.

property pulse_period
A floating point property that controls the period of a pulse waveform function in seconds, ranging from 33 ns to 1e6 s. Can be set and overwrites the frequency for *all* waveforms. If the period is shorter than the pulse width + the edge time, the edge time and pulse width will be adjusted accordingly.

property pulse_transition
A floating point property that controls the edge time in seconds for both the rising and falling edges. It is defined as the time between the 10% and 90% thresholds of the edge. Valid values are between 8.4 ns to 1 µs. Can be set.

property pulse_width
A floating point property that controls the width of a pulse waveform function in seconds, ranging from 16 ns to 1e6 s, within a set of restrictions depending on the period. Can be set.

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

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

property square_dutycycle
A floating point property that controls the duty cycle of a square waveform function in percent, from 0.01% to 99.98%. The duty cycle is limited by the frequency and the minimal pulse width of 16 ns. See manual for more details. Can be set.

trigger()
Send a trigger signal to the function generator.

property trigger_source
A string property that controls the trigger source. Valid values are: IMM<EDIATE> (internal), EXT<ERNAL> (rear input), BUS (via trigger command). This setting can be set.

property voltage_high
A floating point property that controls the upper voltage of the output waveform in V, from -4.990 V to 5 V (must be higher than low voltage by at least 1 mV). Can be set.

property voltage_low
A floating point property that controls the lower voltage of the output waveform in V, from -5 V to 4.990 V (must be lower than high voltage by at least 1 mV). Can be set.

wait_for_trigger(*timeout=3600*, *should_stop=<function Agilent33500.<lambda>>*)
Wait until the triggering has finished or timeout is reached.

Parameters

- **timeout** – The maximum time the waiting is allowed to take. If timeout is exceeded, a TimeoutError is raised. If timeout is set to zero, no timeout will be used.
- **should_stop** – Optional function (returning a bool) to allow the waiting to be stopped before its end.

7.6.10 Agilent 33521A Function/Arbitrary Waveform Generator

class pymeasure.instruments.agilent.**Agilent33521A**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.agilent.agilent33500.Agilent33500*

Represents the Agilent 33521A Function/Arbitrary Waveform Generator. This documentation page shows only methods different from the parent class *Agilent33500*.

property arb_srate
An floating point property that sets the sample rate of the currently selected arbitrary signal. Valid values are 1 µSa/s to 250 MSa/s. This can be set.

property frequency
A floating point property that controls the frequency of the output waveform in Hz, from 1 uHz to 30 MHz, depending on the specified function. Can be set.

7.6.11 Agilent B1500 Semiconductor Parameter Analyzer

Contents

General Information

This instrument driver does not support all configuration options of the B1500 mainframe yet. So far, it is possible to interface multiple SMU modules and source/measure currents and voltages, perform sampling and staircase sweep measurements. The implementation of further measurement functionalities is highly encouraged. Meanwhile the model is managed by Keysight, see the corresponding "Programming Guide" for details on the control methods and their parameters

Command Translation

Alphabetical list of implemented B1500 commands and their corresponding method/attribute names in this instrument driver.

Command	Property/Method
AAD	*SMU.adc_type()*
AB	*abort()*
AIT	*adc_setup()*
AV	*adc_averaging()*
AZ	*adc_auto_zero*
BC	*clear_buffer()*
CL	*SMU.disable()*
CM	*auto_calibration*
CMM	*SMU.meas_op_mode()*
CN	*SMU.enable()*
DI	*SMU.force()* mode: 'CURRENT'
DV	*SMU.force()* mode: 'VOLTAGE'
DZ	*force_gnd()*, *SMU.force_gnd()*
ERRX?	*check_errors()*
FL	*SMU.filter*
FMT	*data_format()*
*IDN?	id()
*LRN?	*query_learn()*, multiple methods to read/format settings directly
MI	*SMU.sampling_source()* mode: 'CURRENT'
ML	*sampling_mode*
MM	*meas_mode()*
MSC	*sampling_auto_abort()*
MT	*sampling_timing()*
MV	*SMU.sampling_source()* mode: 'VOLTAGE'
*OPC?	*check_idle()*
PA	*pause()*
PAD	*parallel_meas*
RI	*meas_range_current*
RM	*SMU.meas_range_current_auto()*
*RST	*reset()*
RV	*meas_range_voltage*

continues on next page

Table 1 – continued from previous page

Command	Property/Method
SSR	*series_resistor*
TSC	*time_stamp*
TSR	*clear_timer()*
UNT?	*query_modules()*
WAT	*wait_time()*
WI	*SMU.staircase_sweep_source()* mode: 'CURRENT'
WM	*sweep_auto_abort()*
WSI	*SMU.synchronous_sweep_source()* mode: 'CURRENT'
WSV	*SMU.synchronous_sweep_source()* mode: 'VOLTAGE'
WT	*sweep_timing()*
WV	*SMU.staircase_sweep_source()* mode: 'VOLTAGE'
XE	*send_trigger()*

Examples

Initialization of the Instrument

```
from pymeasure.instruments.agilent import AgilentB1500

# explicitly define r/w terminations; set sufficiently large timeout in milliseconds or␣
↪None.
b1500=AgilentB1500("GPIB0::17::INSTR", read_termination='\r\n', write_termination='\r\n',
↪ timeout=600000)
# query SMU config from instrument and initialize all SMU instances
b1500.initialize_all_smus()
# set data output format (required!)
b1500.data_format(21, mode=1) #call after SMUs are initialized to get names for the␣
↪channels
```

IV measurement with 4 SMUs

```
# choose measurement mode
b1500.meas_mode('STAIRCASE_SWEEP', *b1500.smu_references) #order in smu_references␣
↪determines order of measurement

# settings for individual SMUs
for smu in b1500.smu_references:
    smu.enable() #enable SMU
    smu.adc_type = 'HRADC' #set ADC to high-resoultion ADC
    smu.meas_range_current = '1 nA'
    smu.meas_op_mode = 'COMPLIANCE_SIDE' # other choices: Current, Voltage, FORCE_SIDE,␣
↪COMPLIANCE_AND_FORCE_SIDE

# General Instrument Settings
# b1500.adc_averaging = 1
# b1500.adc_auto_zero = True
b1500.adc_setup('HRADC','AUTO',6)
```

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```
#b1500.adc_setup('HRADC','PLC',1)

#Sweep Settings
b1500.sweep_timing(0,5,step_delay=0.1) #hold,delay
b1500.sweep_auto_abort(False,post='STOP') #disable auto abort, set post measurement␣
↪output condition to stop value of sweep
# Sweep Source
nop = 11
b1500.smu1.staircase_sweep_source('VOLTAGE','LINEAR_DOUBLE','Auto Ranging',0,1,nop,0.
↪001) #type, mode, range, start, stop, steps, compliance
# Synchronous Sweep Source
b1500.smu2.synchronous_sweep_source('VOLTAGE','Auto Ranging',0,1,0.001) #type, range,␣
↪start, stop, comp
# Constant Output (could also be done using synchronous sweep source with start=stop,␣
↪but then the output is not ramped up)
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3) #output␣
↪starts immediately! (compared to sweeps)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)

#Start Measurement
b1500.check_errors()
b1500.clear_buffer()
b1500.clear_timer()
b1500.send_trigger()

# read measurement data all at once
b1500.check_idle() #wait until measurement is finished
data = b1500.read_data(2*nop) #Factor 2 beacuse of double sweep

#alternatively: read measurement data live
meas = []
for i in range(nop*2):
    read_data = b1500.read_channels(4+1) # 4 measurement channels, 1 sweep source␣
↪(returned due to mode=1 of data_format)
    # process live data for plotting etc.
    # data format for every channel (status code, channel name e.g. 'SMU1', data name e.g
↪'Current Measurement (A)', value)
    meas.append(read_data)

#sweep constant sources back to 0V
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
```

Sampling measurement with 4 SMUs

```
# choose measurement mode
b1500.meas_mode('SAMPLING', *b1500.smu_references) #order in smu_references determines␣
↪order of measurement
number_of_channels = len(b1500.smu_references)

# settings for individual SMUs
for smu in b1500.smu_references:
    smu.enable() #enable SMU
    smu.adc_type = 'HSADC' #set ADC to high-speed ADC
    smu.meas_range_current = '1 nA'
    smu.meas_op_mode = 'COMPLIANCE_SIDE' # other choices: Current, Voltage, FORCE_SIDE,␣
↪COMPLIANCE_AND_FORCE_SIDE

b1500.sampling_mode = 'LINEAR'
# b1500.adc_averaging = 1
# b1500.adc_auto_zero = True
b1500.adc_setup('HSADC','AUTO',1)
#b1500.adc_setup('HSADC','PLC',1)
nop=11
b1500.sampling_timing(2,0.005,nop) #MT: bias hold time, sampling interval, number of␣
↪points
b1500.sampling_auto_abort(False,post='BIAS') #MSC: BASE/BIAS
b1500.time_stamp = True

# Sources
b1500.smu1.sampling_source('VOLTAGE','Auto Ranging',0,1,0.001) #MV/MI: type, range, base,
↪ bias, compliance
b1500.smu2.sampling_source('VOLTAGE','Auto Ranging',0,1,0.001)
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3) #output␣
↪starts immediately! (compared to sweeps)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',-1,stepsize=0.1,pause=20e-3)

#Start Measurement
b1500.check_errors()
b1500.clear_buffer()
b1500.clear_timer()
b1500.send_trigger()

meas=[]
for i in range(nop):
    read_data = b1500.read_channels(1+2*number_of_channels) #Sampling Index + (time␣
↪stamp + measurement value) * number of channels
    # process live data for plotting etc.
    # data format for every channel (status code, channel name e.g. 'SMU1', data name e.g
↪'Current Measurement (A)', value)
    meas.append(read_data)

#sweep constant sources back to 0V
b1500.smu3.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
b1500.smu4.ramp_source('VOLTAGE','Auto Ranging',0,stepsize=0.1,pause=20e-3)
```

Main Classes

Classes to communicate with the instrument:

- *AgilentB1500*: Main instrument class
- *SMU*: Instantiated by main instrument class for every SMU

All *query* commands return a human readable dict of settings. These are intended for debugging/logging/file headers, not for passing to the accompanying setting commands.

class pymeasure.instruments.agilent.agilentB1500.**AgilentB1500**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Agilent B1500 Semiconductor Parameter Analyzer and provides a high-level interface for taking different kinds of measurements.

property smu_references
Returns all SMU instances.

property smu_names
Returns all SMU names.

query_learn(*query_type*)
Queries settings from the instrument (*LRN?). Returns dict of settings.

Parameters **query_type** (*int or str*) – Query type (number according to manual)

query_learn_header(*query_type*, ***kwargs*)
Queries settings from the instrument (*LRN?). Returns dict of settings in human readable format for debugging or file headers. For optional arguments check the underlying definition of *QueryLearn.query_learn_header()*.

Parameters **query_type** (*int or str*) – Query type (number according to manual)

reset()
Resets the instrument to default settings (*RST)

query_modules()
Queries module models from the instrument. Returns dictionary of channel and module type.

Returns Channel:Module Type

Return type dict

initialize_smu(*channel*, *smu_type*, *name*)
Initializes SMU instance by calling *SMU*.

Parameters

- **channel** (*int*) – SMU channel
- **smu_type** (*str*) – SMU type, e.g. 'HRSMU'
- **name** (*str*) – SMU name for pymeasure (data output etc.)

Returns SMU instance

Return type *SMU*

initialize_all_smus()
Initialize all SMUs by querying available modules and creating a SMU class instance for each. SMUs are accessible via attributes .smu1 etc.

pause(*pause_seconds*)
Pauses Command Excecution for given time in seconds (PA)

Parameters **pause_seconds** (*int*) – Seconds to pause

abort()
Aborts the present operation but channels may still output current/voltage (AB)

force_gnd()
Force 0V on all channels immediately. Current Settings can be restored with RZ. (DZ)

check_errors()
Check for errors (ERRX?)

check_idle()
Check if instrument is idle (*OPC?)

clear_buffer()
Clear output data buffer (BC)

clear_timer()
Clear timer count (TSR)

send_trigger()
Send trigger to start measurement (except High Speed Spot) (XE)

property auto_calibration
Enable/Disable SMU auto-calibration every 30 minutes. (CM)

Type bool

data_format(*output_format*, *mode=0*)
Specifies data output format. Check Documentation for parameters. Should be called once per session to set the data format for interpreting the measurement values read from the instrument. (FMT)

Currently implemented are format 1, 11, and 21.

Parameters

- **output_format** (*str*) – Output format string, e.g. FMT21
- **mode** (*int, optional*) – Data output mode, defaults to 0 (only measurement data is returned)

property parallel_meas

Enable/Disable parallel measurements. Effective for SMUs using HSADC and measurement modes 1,2,10,18. (PAD)

Type bool

query_meas_settings()
Read settings for TM, AV, CM, FMT and MM commands (31) from the instrument.

query_meas_mode()
Read settings for MM command (part of 31) from the instrument.

meas_mode(*mode*, **args*)
Set Measurement mode of channels. Measurements will be taken in the same order as the SMU references are passed. (MM)

Parameters

- **mode** (*MeasMode*) – Measurement mode
  - Spot
  - Staircase Sweep

– Sampling

- **args** (*SMU*) – SMU references

query_adc_setup()
Read ADC settings (55, 56) from the intrument.

adc_setup(*adc_type*, *mode*, *N=''*)
Set up operation mode and parameters of ADC for each ADC type. (AIT) Defaults:

- HSADC: Auto N=1, Manual N=1, PLC N=1, Time N=0.000002(s)
- HRADC: Auto N=6, Manual N=3, PLC N=1

Parameters

- **adc_type** (*ADCType*) – ADC type
- **mode** (*ADCMode*) – ADC mode
- **N** (*str, optional*) – additional parameter, check documentation, defaults to ''

adc_averaging(*number*, *mode='Auto'*)
Set number of averaging samples of the HSADC. (AV)

Defaults: N=1, Auto

Parameters

- **number** (*int*) – Number of averages
- **mode** (*AutoManual*, optional) – Mode ('Auto','Manual'), defaults to 'Auto'

property adc_auto_zero
Enable/Disable ADC zero function. Halfs the integration time, if off. (AZ)

Type bool

property time_stamp
Enable/Disable Time Stamp function. (TSC)

Type bool

query_time_stamp_setting()
Read time stamp settings (60) from the instrument.

wait_time(*wait_type*, *N*, *offset=0*)
Configure wait time. (WAT)

Parameters

- **wait_type** (*WaitTimeType*) – Wait time type
- **N** (*float*) – Coefficient for initial wait time, default: 1
- **offset** (*int, optional*) – Offset for wait time, defaults to 0

query_staircase_sweep_settings()
Reads Staircase Sweep Measurement settings (33) from the instrument.

sweep_timing(*hold*, *delay*, *step_delay=0*, *step_trigger_delay=0*, *measurement_trigger_delay=0*)
Sets Hold Time, Delay Time and Step Delay Time for staircase or multi channel sweep measurement. (WT) If not set, all parameters are 0.

Parameters

- **hold** (*float*) – Hold time

- **delay** (*float*) – Delay time
- **step_delay** (*float, optional*) – Step delay time, defaults to 0
- **step_trigger_delay** (*float, optional*) – Trigger delay time, defaults to 0
- **measurement_trigger_delay** (*float, optional*) – Measurement trigger delay time, defaults to 0

sweep_auto_abort(*abort*, *post='START'*)
Enables/Disables the automatic abort function. Also sets the post measurement condition. (WM)

Parameters

- **abort** (*bool*) – Enable/Disable automatic abort
- **post** (*StaircaseSweepPostOutput*, optional) – Output after measurement, defaults to 'Start'

query_sampling_settings()
Reads Sampling Measurement settings (47) from the instrument.

property sampling_mode
Set linear or logarithmic sampling mode. (ML)

Type *SamplingMode*

sampling_timing(*hold_bias*, *interval*, *number*, *hold_base=0*)
Sets Timing Parameters for the Sampling Measurement (MT)

Parameters

- **hold_bias** (*float*) – Bias hold time
- **interval** (*float*) – Sampling interval
- **number** (*int*) – Number of Samples
- **hold_base** (*float, optional*) – Base hold time, defaults to 0

sampling_auto_abort(*abort*, *post='Bias'*)
Enables/Disables the automatic abort function. Also sets the post measurement condition. (MSC)

Parameters

- **abort** (*bool*) – Enable/Disable automatic abort
- **post** (*SamplingPostOutput*, optional) – Output after measurement, defaults to 'Bias'

read_data(*number_of_points*)
Reads all data from buffer and returns Pandas DataFrame. Specify number of measurement points for correct splitting of the data list.

Parameters **number_of_points** (*int*) – Number of measurement points

Returns Measurement Data

Return type pd.DataFrame

read_channels(*nchannels*)
Reads data for 1 measurement point from the buffer. Specify number of measurement channels + sweep sources (depending on data output setting).

Parameters **nchannels** (*int*) – Number of channels which return data

Returns Measurement data

Return type tuple

query_series_resistor()
Read series resistor status (53) for all SMUs.

query_meas_range_current_auto()
Read auto ranging mode status (54) for all SMUs.

query_meas_op_mode()
Read SMU measurement operation mode (46) for all SMUs.

query_meas_ranges()
Read measruement ranging status (32) for all SMUs.

class pymeasure.instruments.agilent.agilentB1500.**SMU**(*parent*, *channel*, *smu_type*, *name*, ***kwargs*)
Bases: object

Provides specific methods for the SMUs of the Agilent B1500 mainframe

Parameters

- **parent** (*AgilentB1500*) – Instance of the B1500 mainframe class
- **channel** (*int*) – Channel number of the SMU
- **smu_type** (*str*) – Type of the SMU
- **name** (*str*) – Name of the SMU

write(*string*)
Wraps *Instrument.write()* method of B1500.

ask(*string*)
Wraps *ask()* method of B1500.

query_learn(*query_type*, *command*)
Wraps *query_learn()* method of B1500.

check_errors()
Wraps *check_errors()* method of B1500.

property status
Query status of the SMU.

enable()
Enable Source/Measurement Channel (CN)

disable()
Disable Source/Measurement Channel (CL)

force_gnd()
Force 0V immediately. Current Settings can be restored with RZ (not implemented). (DZ)

property filter
Enables/Disables SMU Filter. (FL)

Type bool

property series_resistor
Enables/Disables 1MOhm series resistor. (SSR)

Type bool

property meas_op_mode
Set SMU measurement operation mode. (CMM)

Type *MeasOpMode*

property adc_type
ADC type of individual measurement channel. (AAD)

Type *ADCType*

force(*source_type*, *source_range*, *output*, *comp=''*, *comp_polarity=''*, *comp_range=''*)
Applies DC Current or Voltage from SMU immediately. (DI, DV)

Parameters

- **source_type** (*str*) – Source type ('Voltage','Current')
- **source_range** (*int or str*) – Output range index or name
- **output** – Source output value in A or V
- **comp** (*float, optional*) – Compliance value, defaults to previous setting
- **comp_polarity** (*CompliancePolarity*) – Compliance polairty, defaults to auto
- **comp_range** (*int or str, optional*) – Compliance ranging type, defaults to auto

ramp_source(*source_type*, *source_range*, *target_output*, *comp=''*, *comp_polarity=''*, *comp_range=''*, *stepsize=0.001*, *pause=0.02*)
Ramps to a target output from the set value with a given step size, each separated by a pause.

Parameters

- **source_type** (*str*) – Source type ('Voltage' or 'Current')
- **target_output** – Target output voltage or current
- **irange** (*int*) – Output range index
- **comp** (*float, optional*) – Compliance, defaults to previous setting
- **comp_polarity** (*CompliancePolarity*) – Compliance polairty, defaults to auto
- **comp_range** (*int or str, optional*) – Compliance ranging type, defaults to auto
- **stepsize** – Maximum size of steps
- **pause** – Duration in seconds to wait between steps

Type target_output: float

property meas_range_current
Current measurement range index. (RI)

Possible settings depend on SMU type, e.g. 0 for Auto Ranging: *SMUCurrentRanging*

property meas_range_voltage
Voltage measurement range index. (RV)

Possible settings depend on SMU type, e.g. 0 for Auto Ranging: *SMUVoltageRanging*

meas_range_current_auto(*mode*, *rate=50*)
Specifies the auto range operation. Check Documentation. (RM)

Parameters

- **mode** (*int*) – Range changing operation mode
- **rate** (*int, optional*) – Parameter used to calculate the *current* value, defaults to 50

staircase_sweep_source(*source_type*, *mode*, *source_range*, *start*, *stop*, *steps*, *comp*, *Pcomp=''*)
Specifies Staircase Sweep Source (Current or Voltage) and its parameters. (WV or WI)

Parameters

- **source_type** (*str*) – Source type (`'Voltage'`,`'Current'`)
- **mode** (*SweepMode*) – Sweep mode
- **source_range** (*int*) – Source range index
- **start** (*float*) – Sweep start value
- **stop** (*float*) – Sweep stop value
- **steps** (*int*) – Number of sweep steps
- **comp** (*float*) – Compliance value
- **Pcomp** (*float, optional*) – Power compliance, defaults to not set

synchronous_sweep_source(*source_type*, *source_range*, *start*, *stop*, *comp*, *Pcomp=''*)
Specifies Synchronous Staircase Sweep Source (Current or Voltage) and its parameters. (`WSV` or `WSI`)

Parameters

- **source_type** (*str*) – Source type (`'Voltage'`,`'Current'`)
- **source_range** (*int*) – Source range index
- **start** (*float*) – Sweep start value
- **stop** (*float*) – Sweep stop value
- **comp** (*float*) – Compliance value
- **Pcomp** (*float, optional*) – Power compliance, defaults to not set

sampling_source(*source_type*, *source_range*, *base*, *bias*, *comp*)
Sets DC Source (Current or Voltage) for sampling measurement. DV/DI commands on the same channel overwrite this setting. (`MV` or `MI`)

Parameters

- **source_type** (*str*) – Source type (`'Voltage'`,`'Current'`)
- **source_range** (*int*) – Source range index
- **base** (*float*) – Base voltage/current
- **bias** (*float*) – Bias voltage/current
- **comp** (*float*) – Compliance value

Supporting Classes

Classes that provide additional functionalities:

- *QueryLearn*: Process read out of instrument settings
- *SMUCurrentRanging*, *SMUVoltageRanging*: Allowed ranges for different SMU types and transformation of range names to indices (base: *Ranging*)

class pymeasure.instruments.agilent.agilentB1500.**QueryLearn**
Bases: `object`

Methods to issue and process `*LRN?` (learn) command and response.

static query_learn(*ask*, *query_type*)
Issues `*LRN?` (learn) command to the instrument to read configuration. Returns dictionary of commands and set values.

Parameters **query_type** (*int*) – Query type according to the programming guide

Returns Dictionary of command and set values

Return type dict

classmethod query_learn_header(*ask*, *query_type*, *smu_references*, *single_command=False*)
Issues *LRN? (learn) command to the instrument to read configuration. Processes information to human readable values for debugging purposes or file headers.

Parameters

- **ask** (*Instrument.ask*) – ask method of the instrument
- **query_type** (*int or str*) – Number according to Programming Guide
- **smu_references** (*dict*) – SMU references by channel
- **single_command** (*str*) – if only a single command should be returned, defaults to False

Returns Read configuration

Return type dict

static to_dict(*parameters*, *names*, **args*)
Takes parameters returned by *query_learn()* and ordered list of corresponding parameter names (optional function) and returns dict of parameters including names.

Parameters

- **parameters** (*dict*) – Parameters for one command returned by *query_learn()*
- **names** (*list*) – list of names or (name, function) tuples, ordered

Returns Parameter name and (processed) parameter

Return type dict

class pymeasure.instruments.agilent.agilentB1500.**Ranging**(*supported_ranges*, *ranges*, *fixed_ranges=False*)

Bases: object

Possible Settings for SMU Current/Voltage Output/Measurement ranges. Transformation of available Voltage/Current Range Names to Index and back.

Parameters

- **supported_ranges** (*list*) – Ranges which are supported (list of range indizes)
- **ranges** (*dict*) – All range names {Name: Indizes}
- **fixed_ranges** – add fixed ranges (negative indizes); defaults to False

__call__(*input_value*)
Gives named tuple (name/index) of given Range. Throws error if range is not supported by this SMU.

Parameters **input** (*str or int*) – Range name or index

Returns named tuple (name/index) of range

Return type namedtuple

class pymeasure.instruments.agilent.agilentB1500.**SMUCurrentRanging**(*smu_type*)
Bases: object

Provides Range Name/Index transformation for current measurement/sourcing. Validity of ranges is checked against the type of the SMU.

Omitting the 'limited auto ranging'/'range fixed' specification in the range string for current measurement defaults to 'limited auto ranging'.

Full specification: '1 nA range fixed' or '1 nA limited auto ranging'

'1 nA' defaults to '1 nA limited auto ranging'

class pymeasure.instruments.agilent.agilentB1500.**SMUVoltageRanging**(*smu_type*)
Bases: object

Provides Range Name/Index transformation for voltage measurement/sourcing. Validity of ranges is checked against the type of the SMU.

Omitting the 'limited auto ranging'/'range fixed' specification in the range string for voltage measurement defaults to 'limited auto ranging'.

Full specification: '2 V range fixed' or '2 V limited auto ranging'

'2 V' defaults to '2 V limited auto ranging'

Enumerations

Enumerations are used for easy selection of the available parameters (where it is applicable). Methods accept member name or number as input, but name is recommended for readability reasons. The member number is passed to the instrument. Converting an enumeration member into a string gives a title case, whitespace separated string (*__str__()*) which cannot be used to select an enumeration member again. It's purpose is only logging or documentation.

class pymeasure.instruments.agilent.agilentB1500.**CustomIntEnum**(*value*)
Bases: enum.IntEnum

Provides additional methods to IntEnum:

- Conversion to string automatically replaces '_' with ' ' in names and converts to title case
- get classmethod to get enum reference with name or integer

__str__()
Gives title case string of enum value

classmethod get(*input_value*)
Gives Enum member by specifying name or value.

Parameters **input_value** (*str or int*) – Enum name or value

Returns Enum member

class pymeasure.instruments.agilent.agilentB1500.**ADCType**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

ADC Type

HSADC = 0
High-speed ADC

HRADC = 1
High-resolution ADC

HSADC_PULSED = 2
High-resolution ADC for pulsed measurements

class pymeasure.instruments.agilent.agilentB1500.**ADCMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

ADC Mode

AUTO = 0

MANUAL = 1

PLC = 2

TIME = 3

class pymeasure.instruments.agilent.agilentB1500.**AutoManual**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Auto/Manual selection

AUTO = 0

MANUAL = 1

class pymeasure.instruments.agilent.agilentB1500.**MeasMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Measurement Mode

SPOT = 1

STAIRCASE_SWEEP = 2

SAMPLING = 10

class pymeasure.instruments.agilent.agilentB1500.**MeasOpMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Measurement Operation Mode

COMPLIANCE_SIDE = 0

CURRENT = 1

VOLTAGE = 2

FORCE_SIDE = 3

COMPLIANCE_AND_FORCE_SIDE = 4

class pymeasure.instruments.agilent.agilentB1500.**SweepMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Sweep Mode

LINEAR_SINGLE = 1

LOG_SINGLE = 2

LINEAR_DOUBLE = 3

LOG_DOUBLE = 4

class pymeasure.instruments.agilent.agilentB1500.**SamplingMode**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Sampling Mode

LINEAR = 1

LOG_10 = 2
Logarithmic 10 data points/decade

LOG_25 = 3
Logarithmic 25 data points/decade

LOG_50 = 4
Logarithmic 50 data points/decade

LOG_100 = 5
Logarithmic 100 data points/decade

LOG_250 = 6
Logarithmic 250 data points/decade

LOG_5000 = 7
Logarithmic 5000 data points/decade

class pymeasure.instruments.agilent.agilentB1500.**SamplingPostOutput**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Output after sampling

BASE = 1

BIAS = 2

class pymeasure.instruments.agilent.agilentB1500.**StaircaseSweepPostOutput**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Output after staircase sweep

START = 1

STOP = 2

class pymeasure.instruments.agilent.agilentB1500.**CompliancePolarity**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Compliance polarity

AUTO = 0

MANUAL = 1

class pymeasure.instruments.agilent.agilentB1500.**WaitTimeType**(*value*)
Bases: *pymeasure.instruments.agilent.agilentB1500.CustomIntEnum*

Wait time type

SMU_SOURCE = 1

SMU_MEASUREMENT = 2

CMU_MEASUREMENT = 3

7.7 Ametek

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

7.7.1 Ametek 7270 DSP Lockin Amplifier

class pymeasure.instruments.ametek.**Ametek7270**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

This is the class for the Ametek DSP 7270 lockin amplifier

property adc1
Reads the input value of ADC1 in Volts

property adc2
Reads the input value of ADC2 in Volts

property adc3
Reads the input value of ADC3 in Volts

property adc4
Reads the input value of ADC4 in Volts

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

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

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

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

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

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

property id
Reads the instrument identification

property mag
Reads the magnitude in Volts

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

property sensitivity
A floating point property that controls the sensitivity range in Volts, which can take discrete values from 2 nV to 1 V. This property can be set.

set_channel_A_mode()
Sets instrument to channel A mode – assuming it is in voltage mode

set_differential_mode(*lineFiltering=True*)
Sets instrument to differential mode – assuming it is in voltage mode

set_voltage_mode()
Sets instrument to voltage control mode

shutdown()
Ensures the instrument in a safe state

property slope
A integer property that controls the filter slope in dB/octave, which can take the values 6, 12, 18, or 24 dB/octave. This property can be set.

property time_constant
A floating point property that controls the time constant in seconds, which takes values from 10 microseconds to 100,000 seconds. This property can be set.

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

property x
Reads the X value in Volts

property x1
Reads the first harmonic X value in Volts

property x2
Reads the second harmonic X value in Volts

property xy
Reads both the X and Y values in Volts

property y
Reads the Y value in Volts

property y1
Reads the first harmonic Y value in Volts

property y2
Reads the second harmonic Y value in Volts

7.8 AMI

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

7.8.1 AMI 430 Power Supply

class pymeasure.instruments.ami.**AMI430**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the AMI 430 Power supply and provides a high-level for interacting with the instrument.

```
magnet = AMI430("TCPIP::web.address.com::7180::SOCKET")


magnet.coilconst = 1.182                # kGauss/A
magnet.voltage_limit = 2.2              # Sets the voltage limit in V

magnet.target_current = 10              # Sets the target current to 10 A
magnet.target_field = 1                 # Sets target field to 1 kGauss

magnet.ramp_rate_current = 0.0357       # Sets the ramp rate in A/s
magnet.ramp_rate_field = 0.0422         # Sets the ramp rate in kGauss/s
magnet.ramp                             # Initiates the ramping
```

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```
magnet.pause                                # Pauses the ramping
magnet.status                               # Returns the status of the magnet

magnet.ramp_to_current(5)                 # Ramps the current to 5 A

magnet.shutdown()                         # Ramps the current to zero and disables␣
↪output
```

property coilconst
A floating point property that sets the coil contant in kGauss/A.

disable_persistent_switch()
Disables the persistent switch.

enable_persistent_switch()
Enables the persistent switch.

property field
Reads the field in kGauss of the magnet.

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

property magnet_current
Reads the current in Amps of the magnet.

pause()
Pauses the ramping of the magnetic field.

ramp()
Initiates the ramping of the magnetic field to set current/field with ramping rate previously set.

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

property ramp_rate_field
A floating point property that sets the field ramping rate in kGauss/s.

ramp_to_current(*current*, *rate*)
Heats up the persistent switch and ramps the current with set ramp rate.

ramp_to_field(*field*, *rate*)
Heats up the persistent switch and ramps the current with set ramp rate.

shutdown(*ramp_rate=0.0357*)
Turns on the persistent switch, ramps down the current to zero, and turns off the persistent switch.

property state
Reads the field in kGauss of the magnet.

property supply_current
Reads the current in Amps of the power supply.

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

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

property voltage_limit
A floating point property that sets the voltage limit for charging/discharging the magnet.

wait_for_holding(*should_stop=<function AMI430.<lambda>>*, *timeout=800*, *interval=0.1*)

zero()
Initiates the ramping of the magnetic field to zero current/field with ramping rate previously set.

7.9 Anaheim Automation

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

7.9.1 DP-Series Step Motor Controller

The DPSeriesMotorController class implements a base driver class for Anaheim-Automation DP Series stepper motor controllers. There are many controllers sold in this series, all of which implement the same core command set. Some controllers, like the DPY50601, implement additional functionality that is not included in this driver. If these additional features are desired, they should be implemented in a subclass.

class pymeasure.instruments.anaheimautomation.**DPSeriesMotorController**(*resourceName*, *address=0*, *encoder_enabled=False*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Base class to interface with Anaheim Automation DP series stepper motor controllers. This driver has been tested with the DPY50601 and DPE25601 motor controllers.

property absolute_position
Float property representing the value of the motor position measured in absolute units. Note that in DP series motor controller instrument manuals, *absolute position* refers to the 'step_position' property rather than this property. Also note that use of this property relies on steps_to_absolute() and absolute_to_steps() being implemented in a subclass. In this way, the user can define the conversion from a motor step position into any desired absolute unit. Absolute units could be the position in meters of a linear stage or the angular position of a gimbal mount, etc. This property can be set.

absolute_to_steps(*pos*)
Convert an absolute position to a number of steps to move. This must be implemented in subclasses.

Parameters pos – Absolute position in the units determined by the subclassed absolute_to_steps() method.

property address
Integer property representing the address that the motor controller uses for serial communications.

ask(*command*)
Override the instrument base ask method to add the motor controller's address to the command string.

Parameters command – command string to be sent to the instrument

property basespeed
Integer property that represents the motor controller's starting/homing speed. This property can be set.

property busy
Query to see if the controller is currently moving a motor.

check_errors()
Method to read the error codes register and log when an error is detected.

Return error_code one byte with the error codes register contents

property direction
A string property that represents the direction in which the stepper motor will rotate upon subsequent step commands. This property can be set. 'CW' corresponds to clockwise rotation and 'CCW' corresponds to counter-clockwise rotation.

property encoder_autocorrect
A boolean property to enable or disable the encoder auto correct function. This property can be set.

property encoder_delay
An integer property that represents the wait time in ms. after a move is finished before the encoder is read for a potential encoder auto-correct action to take place. This property can be set.

property encoder_enabled
A boolean property to represent whether an external encoder is connected and should be used to set the step_position property.

property encoder_motor_ratio
An integer property that represents the ratio of the number of encoder pulses per motor step. This property can be set.

property encoder_retries
An integer property that represents the number of times the motor controller will try the encoder auto correct function before setting an error flag. This property can be set.

property encoder_window
An integer property that represents the allowable error in encoder pulses from the desired position before the encoder auto-correct function runs. This property can be set.

property error_reg
Reads the current value of the error codes register.

home(*home_mode*)
Send command to the motor controller to 'home' the motor.

Parameters **home_mode** – 0 or 1 specifying which homing mode to run.

0 will perform a homing operation where the controller moves the motor until a soft limit is reached, then will ramp down to base speed and continue motion until a home limit is reached.

In mode 1, the controller will move the motor until a limit is reached, then will ramp down to base speed, change direction, and run until the limit is released.

property maxspeed
Integer property that represents the motor controller's maximum (running) speed. This property can be set.

move(*direction*)

Move the stepper motor continuously in the given direction until a stop command is sent or a limit switch is reached. This method corresponds to the 'slew' command in the DP series instrument manuals.

Parameters **direction** – value to set on the direction property before moving the motor.

reset_position()
Reset the position as counted by the motor controller and an externally connected encoder to 0.

property step_position
Integer property representing the value of the motor position measured in steps counted by the motor controller or, if encoder_enabled is set, the steps counted by an externally connected encoder. Note that in the

DP series motor controller instrument manuals, this property would be referred to as the 'absolute position' while this driver implements a conversion between steps and absolute units for the *absolute position* property. This property can be set.

steps_to_absolute(*steps*)
Convert a position measured in steps to an absolute position.

Parameters **steps** – Position in steps to be converted to an absolute position.

stop()
Method that stops all motion on the motor controller.

values(*command*, ***kwargs*)
Override the instrument base values method to add the motor controller's address to the command string.

Parameters **command** – command string to be sent to the motor controller.

wait_for_completion(*interval=0.5*)
Block until the controller is not "busy" (i.e. block until the motor is no longer moving.)

Parameters **interval** – (float) seconds between queries to the "busy" flag.

Returns None

write(*command*)
Override the instrument base write method to add the motor controller's address to the command string.

Parameters **command** – command string to be sent to the motor controller.

7.10 Anapico

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

7.10.1 Anapico APSIN12G Signal Generator

class pymeasure.instruments.anapico.**APSIN12G**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Anapico APSIN12G Signal Generator with option 9K, HP and GPIB.

property blanking
A string property that represents the blanking of output power when frequency is changed. ON makes the output to be blanked (off) while changing frequency. This property can be set.

disable_rf()
Disables the RF output.

enable_rf()
Enables the RF output.

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

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

property reference_output
A string property that represents the 10MHz reference output from the synth. This property can be set.

7.11 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*.

7.11.1 Anritsu MG3692C Signal Generator

class pymeasure.instruments.anritsu.**AnritsuMG3692C**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Anritsu MG3692C Signal Generator

disable()
Disables the signal output.

enable()
Enables the signal output.

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

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

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

shutdown()
Shuts down the instrument, putting it in a safe state.

7.11.2 Anritsu MS9710C Optical Spectrum Analyzer

class pymeasure.instruments.anritsu.**AnritsuMS9710C**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Anritsu MS9710C Optical Spectrum Analyzer.

property analysis
Analysis Control

property analysis_result
Read back anaysis result from current scan.

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

property average_sweep
Number of averages to make on a sweep (2-1000) or OFF

center_at_peak(***kwargs*)
Center the spectrum at the measured peak.

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

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

property data_memory_a_values
Reads the binary data from memory register A.

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

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

property data_memory_b_values
Reads the binary data from memory register B.

property data_memory_select
Memory Data Select.

property dip_search
Dip Search Mode

property ese2
Extended Event Status Enable Register 2

property esr2
Extended Event Status Register 2

property level_lin
Level Linear Scale (/div)

property level_log
Level Log Scale (/div)

property level_opt_attn
Optical Attenuation Status (ON/OFF)

property level_scale
Current Level Scale

property measure_mode
Returns the current Measure Mode the OSA is in.

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

property peak_search
Peak Search Mode

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

property resolution
Resolution (nm)

property resolution_actual
Resolution Actual (ON/OFF)

property resolution_vbw
Video Bandwidth Resolution

property sampling_points
Number of sampling points

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

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

property trace_marker_center
Trace Marker at Center. Set to 1 or True to initiate command

wait(*n=3*, *delay=1*)
Query OPC Command and waits for appropriate response.

wait_for_sweep(*n=20*, *delay=0.5*)
Wait for a sweep to stop.

This is performed by checking bit 1 of the ESR2.

property wavelength_center
Center Wavelength of Spectrum Scan in nm.

property wavelength_marker_value
Wavelength Marker Value (wavelength or freq.?)

property wavelength_span
Wavelength Span of Spectrum Scan in nm.

property wavelength_start
Wavelength Start of Spectrum Scan in nm.

property wavelength_stop
Wavelength Stop of Spectrum Scan in nm.

property wavelength_value_in
Wavelength value in Vacuum or Air

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

7.12 Attocube

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

7.12.1 Attocube Adapters

class pymeasure.instruments.attocube.adapters.**AttocubeConsoleAdapter**(*host*, *port*, *passwd*, ***kwargs*)

Bases: *pymeasure.adapters.telnet.TelnetAdapter*

Adapter class for connecting to the Attocube Standard Console. This console is a Telnet prompt with password authentication.

Parameters

- **host** – host address of the instrument
- **port** – TCPIP port
- **passwd** – password required to open the connection
- **kwargs** – Any valid key-word argument for TelnetAdapter

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

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

Returns String ASCII response of the instrument

check_acknowledgement(*reply*, *msg=''*)
checks the last reply of the instrument to be 'OK', otherwise a ValueError is raised.

Parameters

- **reply** – last reply string of the instrument
- **msg** – optional message for the eventual error

extract_value(*reply*)
preprocess_reply function for the Attocube console. This function tries to extract <value> from 'name = <value> [unit]'. If <value> can not be identified the original string is returned.

Parameters **reply** – reply string

Returns string with only the numerical value, or the original string

read()
Reads a reply of the instrument which consists of two or more lines. The first ones are the reply to the command while the last one is 'OK' or 'ERROR' to indicate any problem. In case the reply is not OK a ValueError is raised.

Returns String ASCII response of the instrument.

write(*command*, *check_ack=True*)
Writes a command to the instrument

Parameters

- **command** – command string to be sent to the instrument
- **check_ack** – boolean flag to decide if the acknowledgement is read back from the instrument. This should be True for set pure commands and False otherwise.

7.12.2 Attocube ANC300 Motion Controller

class pymeasure.instruments.attocube.anc300.**ANC300Controller**(*host*, *axisnames*, *passwd*, *query_delay=0.05*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Attocube ANC300 Piezo stage controller with several axes

Parameters

- **host** – host address of the instrument
- **axisnames** – a list of axis names which will be used to create properties with these names
- **passwd** – password for the attocube standard console
- **query_delay** – delay between sending and reading (default 0.05 sec)
- **kwargs** – Any valid key-word argument for TelnetAdapter

property controllerBoardVersion
Serial number of the controller board

ground_all()
Grounds all axis of the controller.

stop_all()
Stop all movements of the axis.

property version
Version number and instrument identification

class pymeasure.instruments.attocube.anc300.**Axis**(*controller*, *axis*)
Bases: object

Represents a single open loop axis of the Attocube ANC350

Parameters

- **axis** – axis identifier, integer from 1 to 7
- **controller** – ANC300Controller instance used for the communication

property capacity
Saved capacity value in nF of the axis.

property frequency
Frequency of the stepping motion in Hertz from 1 to 10000 Hz. This property can be set.

measure_capacity()
Obtains a new measurement of the capacity. The mode of the axis returns to 'gnd' after the measurement.

Returns capacity the freshly measured capacity in nF.

property mode
Axis mode. This can be 'gnd', 'inp', 'cap', 'stp', 'off', 'stp+', 'stp-'. Available modes depend on the actual axis model

move(*steps*, *gnd=True*)
Move 'steps' steps in the direction given by the sign of the argument. This method will change the mode of the axis automatically and ground the axis on the end if 'gnd' is True. The method returns only when the movement is finished.

Parameters

- **steps** – finite integer value of steps to be performed. A positive sign corresponds to upwards steps, a negative sign to downwards steps.
- **gnd** – bool, flag to decide if the axis should be grounded after completion of the movement

property offset_voltage
Offset voltage in Volts from 0 to 150 V. This property can be set.

property output_voltage
Output voltage in volts.

property pattern_down
step down pattern of the piezo drive. 256 values ranging from 0 to 255 representing the the sequence of output voltages within one step of the piezo drive. This property can be set, the set value needs to be an array with 256 integer values.

property pattern_up
step up pattern of the piezo drive. 256 values ranging from 0 to 255 representing the the sequence of output voltages within one step of the piezo drive. This property can be set, the set value needs to be an array with 256 integer values.

property serial_nr
Serial number of the axis

property stepd
Step downwards for N steps. Mode must be 'stp' and N must be positive.

property stepu
Step upwards for N steps. Mode must be 'stp' and N must be positive.

stop()
Stop any motion of the axis

property voltage
Amplitude of the stepping voltage in volts from 0 to 150 V. This property can be set.

7.13 BK Precision

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

7.13.1 BK Precision 9130B DC Power Supply

class pymeasure.instruments.bkprecision.**BKPrecision9130B**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the BK Precision 9130B DC Power Supply interface for interacting with the instrument.

property channel
An integer property used to control which channel is selected. Can only take values [1, 2, 3].

check_errors()
Read all errors from the instrument.

Returns list of error entries

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

property current
Floating point property used to control current of the selected channel.

property id
Requests and returns the identification of the instrument.

property options
Requests and returns the device options installed.

reset()
Resets the instrument.

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

property source_enabled
A boolean property that controls whether the source is enabled, takes values True or False.

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

property voltage
Floating point property used to control voltage of the selected channel.

7.14 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*.

7.14.1 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

7.14.2 Danfysik 8500 Power Supply

class pymeasure.instruments.danfysik.**Danfysik8500**(*port*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Danfysik 8500 Electromanget Current Supply and provides a high-level interface for interacting with the instrument

To allow user access to the Prolific Technology PL2303 Serial port adapter in Linux, create the file: /etc/udev/rules.d/50-danfysik.rules, with contents:

```
SUBSYSTEMS=="usb",ATTRS{idVendor}=="067b",ATTRS{idProduct}=="2303",MODE="0666",
↪SYMLINK+="danfysik"
```

Then reload the udev rules with:

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

The device will be accessible through the port /dev/danfysik.

add_ramp_step(*current*)
Adds a current step to the ramp set.

Parameters **current** – A current in Amps

clear_ramp_set()
Clears the ramp set.

clear_sequence(*stack*)
Clears the sequence by the stack number.

Parameters **stack** – A stack number between 0-15

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

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

property current_setpoint
The setpoint for the current, which can deviate from the actual current (*current*) while the supply is in the process of setting the value.

disable()
Disables the flow of current.

enable()
Enables the flow of current.

property id
Reads the idenfitication information.

is_current_stable()
Returns True if the current is within 0.02 A of the setpoint value.

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

is_ready()
Returns True if the instrument is in the ready state.

is_sequence_running(*stack*)
Returns True if a sequence is running with a given stack number

Parameters **stack** – A stack number between 0-15

local()
Sets the instrument in local mode, where the front panel can be used.

property polarity
The polarity of the current supply, being either -1 or 1. This property can be set by suppling one of these values.

ramp_to_current(*current*, *points*, *delay_time=1*)
Executes *set_ramp_to_current()* and starts the ramp.

remote()
Sets the instrument in remote mode, where the the front panel is disabled.

reset_interlocks()
Resets the instrument interlocks.

set_ramp_delay(*time*)
Sets the ramp delay time in seconds.

Parameters **time** – The time delay time in seconds

set_ramp_to_current(*current*, *points*, *delay_time=1*)
Sets up a linear ramp from the initial current to a different current, with a number of points, and delay time.

Parameters

- **current** – The final current in Amps
- **points** – The number of linear points to traverse
- **delay_time** – A delay time in seconds

set_sequence(*stack*, *currents*, *times*, *multiplier=999999*)
Sets up an arbitrary ramp profile with a list of currents (Amps) and a list of interval times (seconds) on the specified stack number (0-15)

property slew_rate
The slew rate of the current sweep.

start_ramp()
Starts the current ramp.

start_sequence(*stack*)
Starts a sequence by the stack number.

Parameters **stack** – A stack number between 0-15

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

property status_hex
The status in hexadecimal. This value is parsed in *status* into a human-readable list.

stop_ramp()
Stops the current ramp.

stop_sequence()
Stops the currently running sequence.

sync_sequence(*stack*, *delay=0*)
Arms the ramp sequence to be triggered by a hardware input to pin P33 1&2 (10 to 24 V) or a TS command. If a delay is provided, the sequence will start after the delay.

Parameters

- **stack** – A stack number between 0-15
- **delay** – A delay time in seconds

wait_for_current(*has_aborted=<function Danfysik8500.<lambda>>*, *delay=0.01*)
Blocks the process until the current has stabilized. A provided function has_aborted can be supplied, which is checked after each delay time (in seconds) in addition to the stability check. This allows an abort feature to be integrated.

Parameters

- **has_aborted** – A function that returns True if the process should stop waiting
- **delay** – The delay time in seconds between each check for stability

wait_for_ready(*has_aborted=<function Danfysik8500.<lambda>>*, *delay=0.01*)
Blocks the process until the instrument is ready. A provided function has_aborted can be supplied, which is checked after each delay time (in seconds) in addition to the readiness check. This allows an abort feature to be integrated.

Parameters

- **has_aborted** – A function that returns True if the process should stop waiting
- **delay** – The delay time in seconds between each check for readiness

7.15 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*.

7.15.1 Delta Elektronica SM7045D Power source

class pymeasure.instruments.deltaelektronika.**SM7045D**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

This is the class for the SM 70-45 D power supply.

```
source = SM7045D("GPIB::8")

source.ramp_to_zero(1)              # Set output to 0 before enabling
source.enable()                     # Enables the output
source.current = 1                  # Sets a current of 1 Amps
```

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

disable()
Enables remote shutdown, hence input will be disabled.

enable()
Disable remote shutdown, hence output will be enabled.

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

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

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

property measure_voltage
Measures the actual output voltage of the power supply in Volts.

ramp_to_current(*target_current*, *current_step=0.1*)
Gradually increase/decrease current to target current.

Parameters

- **target_current** – Float that sets the target current (in A)
- **current_step** – Optional float that sets the current steps / ramp rate (in A/s)

ramp_to_zero(*current_step=0.1*)
Gradually decrease the current to zero.

Parameters **current_step** – Optional float that sets the current steps / ramp rate (in A/s)

property rsd
Check whether remote shutdown is enabled/disabled and thus if the output of the power supply is disabled/enabled.

shutdown()
Set the current to 0 A and disable the output of the power source.

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

7.16 Edwards

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

7.16.1 Edwards nxds vacuum pump

pymeasure.instruments.edwards.**nxds**

7.17 Fluke

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

7.17.1 Fluke 7341 Temperature bath

class pymeasure.instruments.fluke.**Fluke7341**(*resource_name*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the compact constant temperature bath from Fluke

property id
Read the instrument model

property set_point
A *float* property to set the bath temperature set-point. Valid values are in the range –40 to 150 °C. The unit is as defined in property *unit*. This property can be read

property temperature
Read the current bath temperature. The unit is as defined in property *unit*.

property unit
A string property that controls the temperature unit. Possible values are *c* for Celsius and *f* for Fahrenheit`.

7.18 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*.

7.18.1 F.W. Bell 5080 Handheld Gaussmeter

class pymeasure.instruments.fwbell.**FWBell5080**(*port*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the F.W. Bell 5080 Handheld Gaussmeter and provides a high-level interface for interacting with the instrument

Parameters **port** – The serial port of the instrument

```
meter = FWBell5080('/dev/ttyUSB0')      # Connects over serial port /dev/ttyUSB0␣
↪(Linux)

meter.units = 'gauss'                   # Sets the measurement units to Gauss
meter.range = 3e3                       # Sets the range to 3 kG
print(meter.field)                      # Reads and prints a field measurement in G

fields = meter.fields(100)              # Samples 100 field measurements
print(fields.mean(), fields.std())      # Prints the mean and standard deviation of␣
↪the samples
```

ask(*command*)

Overwrites the *Instrument.ask* method to remove the last 2 characters from the output.

auto_range()

Enables the auto range functionality.

property field

Reads a floating point value of the field in the appropriate units.

fields(*samples=1*)

Returns a numpy array of field samples for a given sample number.

Parameters **samples** – The number of samples to preform

property id

Reads the idenfitication information.

property range

A floating point property that controls the maximum field range in the active units. This can take the values of 300 G, 3 kG, and 30 kG for Gauss, 30 mT, 300 mT, and 3 T for Tesla, and 23.88 kAm, 238.8 kAm, and 2388 kAm for Amp-meter.

read()

Overwrites the *Instrument.read* method to remove the last 2 characters from the output.

reset()

Resets the instrument.

property units

A string property that controls the field units, which can take the values: ‘gauss’, ‘gauss ac’, ‘tesla’, ‘tesla ac’, ‘amp-meter’, and ‘amp-meter ac’. The AC versions configure the instrument to measure AC.

values(*command*)
Overwrites the *Instrument.values* method to remove the lastv2 characters from the output.

7.19 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*.

7.19.1 HP 33120A Arbitrary Waveform Generator

class pymeasure.instruments.hp.**HP33120A**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Hewlett Packard 33120A Arbitrary Waveform Generator and provides a high-level interface for interacting with the instrument.

property amplitude
A floating point property that controls the voltage amplitude of the output signal. The default units are in peak-to-peak Volts, but can be controlled by *amplitude_units*. The allowed range depends on the waveform shape and can be queried with *max_amplitude* and *min_amplitude*.

property amplitude_units
A string property that controls the units of the amplitude, which can take the values Vpp, Vrms, dBm, and default.

beep()
Causes a system beep.

property frequency
A floating point property that controls the frequency of the output in Hz. The allowed range depends on the waveform shape and can be queried with *max_frequency* and *min_frequency*.

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

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

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

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

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

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

property offset
A floating point property that controls the amplitude voltage offset in Volts. The allowed range depends on the waveform shape and can be queried with *max_offset* and *min_offset*.

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

7.19.2 HP 34401A Multimeter

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

Represents the HP 34401A instrument.

property current_ac
AC current, in Amps

property current_dc
DC current, in Amps

property resistance
Resistance, in Ohms

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

property voltage_ac
AC voltage, in Volts

property voltage_dc
DC voltage, in Volts

7.19.3 HP 3478A Multimeter

class pymeasure.instruments.hp.**HP3478A**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Hewlett Packard 3748A 5 1/2 digit multimeter and provides a high-level interface for interacting with the instrument.

class ERRORS(*value*)
Bases: enum.IntFlag

Enum element for errror bit decoding

GPIB_trigger()
Initate trigger via low-level GPIB-command (aka GET - group execute trigger)

class SRQ(*value*)
Bases: enum.IntFlag

Enum element for SRQ mask bit decoding

property SRQ_mask
Return current SRQ mask, this property can be set,

bit assigment for SRQ:

Bit (dec)	Description
1	SRQ when Data ready
4	SRQ when Syntax error
8	SRQ when internal error
16	front panel SQR button
32	SRQ by invalid calibration

property active_connectors
Return selected connectors (“front”/”back”), based on front-panel selector switch

property auto_range_enabled
Property describing the auto-ranging status

Value	Status
True	auto-range function activated
False	manual range selection / auto-range disabled

The range can be set with the *range* property

property auto_zero_enabled
Return auto-zero status, this property can be set

Value	Status
True	auto-zero active
False	auto-zero disabled

property calibration_enabled
Return calibration enable switch setting, based on front-panel selector switch

Value	Status
True	calbration possible
False	calibration locked

check_errors()
Method to read the error status register

Return error_status one byte with the error status register content

Rtype error_status int

classmethod decode_mode(*function*)
Method to decode current mode

Parameters **function** – int indicating the measurement function selected

Return cur_mode string with the current measurement mode

Rtype cur_mode str

classmethod decode_range(*range_undecoded*, *function*)
Method to decode current range

Parameters

- **range_undecoded** – int to be decoded
- **function** – int indicating the measurement function selected

Return cur_range float value repesenting the active measurment range

Rtype cur_range float

classmethod decode_status(*status_bytes*, *field=None*)
Method to handle the decoding of the status bytes into something meaningfull

Parameters

- **status_bytes** – list of bytes to be decoded
- **field** – name of field to be returned

Return ret_val int status value

`static decode_trigger(status_bytes)`
Method to decode trigger mode

Parameters `status_bytes` – list of bytes to be decoded

Return trigger_mode string with the current trigger mode

Rtype trigger_mode str

`display_reset()`
Reset the display of the instrument.

`property display_text`
Displays up to 12 upper-case ASCII characters on the display.

`property display_text_no_symbol`
Displays up to 12 upper-case ASCII characters on the display and disables all symbols on the display.

`property error_status`
Checks the error status register

`get_status()`
Method to read the status bytes from the instrument :return current_status: a byte array representing the instrument status :rtype current_status: bytes

`property measure_ACI`
Returns the measured value for AC current as a float in A.

`property measure_ACV`
Returns the measured value for AC Voltage as a float in V.

`property measure_DCI`
Returns the measured value for DC current as a float in A.

`property measure_DCV`
Returns the measured value for DC Voltage as a float in V.

`property measure_R2W`
Returns the measured value for 2-wire resistance as a float in Ohm.

`property measure_R4W`
Returns the measured value for 4-wire resistance as a float in Ohm.

`property measure_Rext`
Returns the measured value for extended resistance mode (>30M, 2-wire) resistance as a float in Ohm.

`property mode`
Return current selected measurement mode, this propery can be set. Allowed values are

Mode	Function
ACI	AC current
ACV	AC voltage
DCI	DC current
DCV	DC voltage
R2W	2-wire resistance
R4W	4-wire resistance
Rext	extended resistance method (requires additional 10 M resistor)

`property range`
Returns the current measurement range, this property can be set.

Valid values are :

Mode	Range
ACI	0.3, 3, auto
ACV	0.3, 3, 30, 300, auto
DCI	0.3, 3, auto
DCV	0.03, 0.3, 3, 30, 300, auto
R2W	30, 300, 3000, 3E4, 3E5, 3E6, 3E7, auto
R4W	30, 300, 3000, 3E4, 3E5, 3E6, 3E7, auto
Rext	3E7, auto

reset()
Initatiates a reset (like a power-on reset) of the HP3478A

property resolution
Returns current selected resolution, this property can be set.

Possible values are 3,4 or 5 (for 3 1/2, 4 1/2 or 5 1/2 digits of resolution)

shutdown()
provides a way to gracefully close the connection to the HP3478A

property status
Returns an object representing the current status of the unit.

property trigger
Return current selected trigger mode, this property can be set

Possibe values are:

Value	Meaning
auto	automatic trigger (internal)
internal	automatic trigger (internal)
external	external trigger (connector on back or GET)
hold	holds the measurement
fast	fast trigger for AC measurements

7.20 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*.

7.20.1 Keithley 2000 Multimeter

class pymeasure.instruments.keithley.**Keithley2000**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithley 2000 Multimeter and provides a high-level interface for interacting with the instrument.

```
meter = Keithley2000("GPIB::1")
meter.measure_voltage()
print(meter.voltage)
```

acquire_reference(*mode=None*)
Sets the active value as the reference for the active mode, or can set another mode by its name.

Parameters **mode** – A valid *mode* name, or None for the active mode

auto_range(*mode=None*)
Sets the active mode to use auto-range, or can set another mode by its name.

Parameters **mode** – A valid *mode* name, or None for the active mode

beep(*frequency*, *duration*)
Sounds a system beep.

Parameters

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

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

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

check_errors()
Read all errors from the instrument.

Returns list of error entries

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

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

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

property current_ac_bandwidth
A floating point property that sets the AC current detector bandwidth in Hz, which can take the values 3, 30, and 300 Hz.

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

property current_ac_nplc
A floating point property that controls the number of power line cycles (NPLC) for the AC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property current_ac_range
A floating point property that controls the AC current range in Amps, which can take values from 0 to 3.1 A. Auto-range is disabled when this property is set.

property current_ac_reference
A floating point property that controls the AC current reference value in Amps, which can take values from -3.1 to 3.1 A.

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

property current_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property current_range
A floating point property that controls the DC current range in Amps, which can take values from 0 to 3.1 A. Auto-range is disabled when this property is set.

property current_reference
A floating point property that controls the DC current reference value in Amps, which can take values from -3.1 to 3.1 A.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

disable_filter(*mode=None*)
Disables the averaging filter for the active mode, or can set another mode by its name.

Parameters **mode** – A valid *mode* name, or None for the active mode

disable_reference(*mode=None*)
Disables the reference for the active mode, or can set another mode by its name.

Parameters **mode** – A valid *mode* name, or None for the active mode

enable_filter(*mode=None*, *type='repeat'*, *count=1*)
Enables the averaging filter for the active mode, or can set another mode by its name.

Parameters

- **mode** – A valid *mode* name, or None for the active mode
- **type** – The type of averaging filter, either 'repeat' or 'moving'.
- **count** – A number of averages, which can take take values from 1 to 100

enable_reference(*mode=None*)
Enables the reference for the active mode, or can set another mode by its name.

Parameters **mode** – A valid *mode* name, or None for the active mode

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

property frequency_aperature
A floating point property that controls the frequency aperature in seconds, which sets the integration period and measurement speed. Takes values from 0.01 to 1.0 s.

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

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

property frequency_threshold
A floating point property that controls the voltage signal threshold level in Volts for the frequency measurement, which can take values from 0 to 1010 V.

property id
Requests and returns the identification of the instrument.

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

local()
Returns control to the instrument panel, and enables the panel if disabled.

measure_continuity()
Configures the instrument to perform continuity testing.

measure_current(*max_current=0.01*, *ac=False*)
Configures the instrument to measure current, based on a maximum current to set the range, and a boolean flag to determine if DC or AC is required.

Parameters

- **max_current** – A current in Volts to set the current range
- **ac** – False for DC current, and True for AC current

measure_diode()
Configures the instrument to perform diode testing.

measure_frequency()
Configures the instrument to measure the frequency.

measure_period()
Configures the instrument to measure the period.

measure_resistance(*max_resistance=10000000.0*, *wires=2*)
Configures the instrument to measure voltage, based on a maximum voltage to set the range, and a boolean flag to determine if DC or AC is required.

Parameters

- **max_voltage** – A voltage in Volts to set the voltage range
- **ac** – False for DC voltage, and True for AC voltage

measure_temperature()
Configures the instrument to measure the temperature.

measure_voltage(*max_voltage=1*, *ac=False*)
Configures the instrument to measure voltage, based on a maximum voltage to set the range, and a boolean flag to determine if DC or AC is required.

Parameters

- **max_voltage** – A voltage in Volts to set the voltage range
- **ac** – False for DC voltage, and True for AC voltage

property mode
A string property that controls the configuration mode for measurements, which can take the values:

:code:'current' (DC), :code:'current ac', :code:'voltage' (DC), :code:'voltage ac', :code:'resistance' (2-wire), :code:'resistance 4W' (4-wire), :code:'period', :code:'frequency', :code:'temperature', :code:'diode', and :code:'frequency'.

property options
Requests and returns the device options installed.

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

property period_aperature
A floating point property that controls the period aperature in seconds, which sets the integration period and measurement speed. Takes values from 0.01 to 1.0 s.

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

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

property period_threshold
A floating point property that controls the voltage signal threshold level in Volts for the period measurement, which can take values from 0 to 1010 V.

remote()
Places the instrument in the remote state, which is does not need to be explicity called in general.

remote_lock()
Disables and locks the front panel controls to prevent changes during remote operations. This is disabled by calling *local()*.

reset()
Resets the instrument state.

reset_buffer()
Resets the buffer.

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

property resistance_4W_digits
An integer property that controls the number of digits in the 4-wire resistance readings, which can take values from 4 to 7.

property resistance_4W_nplc
A floating point property that controls the number of power line cycles (NPLC) for the 4-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property resistance_4W_range
A floating point property that controls the 4-wire resistance range in Ohms, which can take values from 0 to 120 MOhms. Auto-range is disabled when this property is set.

property resistance_4W_reference
A floating point property that controls the 4-wire resistance reference value in Ohms, which can take values from 0 to 120 MOhms.

property resistance_digits
An integer property that controls the number of digits in the 2-wire resistance readings, which can take values from 4 to 7.

property resistance_nplc
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property resistance_range
A floating point property that controls the 2-wire resistance range in Ohms, which can take values from 0 to 120 MOhms. Auto-range is disabled when this property is set.

property resistance_reference
A floating point property that controls the 2-wire resistance reference value in Ohms, which can take values from 0 to 120 MOhms.

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

start_buffer()
Starts the buffer.

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

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

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

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

property temperature_nplc
A floating point property that controls the number of power line cycles (NPLC) for the temperature measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

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

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

property trigger_delay
A floating point property that controls the trigger delay in seconds, which can take values from 1 to 9,999,999.999 s.

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

property voltage_ac_bandwidth
A floating point property that sets the AC voltage detector bandwidth in Hz, which can take the values 3, 30, and 300 Hz.

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

property voltage_ac_nplc
A floating point property that controls the number of power line cycles (NPLC) for the AC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property voltage_ac_range
A floating point property that controls the AC voltage range in Volts, which can take values from 0 to 757.5 V. Auto-range is disabled when this property is set.

property voltage_ac_reference
A floating point property that controls the AC voltage reference value in Volts, which can take values from -757.5 to 757.5 Volts.

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

property voltage_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property voltage_range
A floating point property that controls the DC voltage range in Volts, which can take values from 0 to 1010 V. Auto-range is disabled when this property is set.

property voltage_reference
A floating point property that controls the DC voltage reference value in Volts, which can take values from -1010 to 1010 V.

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

7.20.2 Keithley 2260B DC Power Supply

class pymeasure.instruments.keithley.**Keithley2260B**(*adapter*, *read_termination='\n'*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keithley 2260B Power Supply (minimal implementation) and provides a high-level interface for interacting with the instrument.

For a connection through tcpip, the device only accepts connections at port 2268, which cannot be configured otherwise. example connection string: 'TCPIP::xxx.xxx.xxx.xxx::2268::SOCKET' the read termination for this interface is

```
source = Keithley2260B("GPIB::1")
source.voltage = 1
print(source.voltage)
print(source.current)
print(source.power)
print(source.applied)
```

property applied
Simultaneous control of voltage (volts) and current (amps). Values need to be supplied as tuple of (voltage, current). Depending on whether the instrument is in constant current or constant voltage mode, the values achieved by the instrument will differ from the ones set.

check_errors()
Logs any system errors reported by the instrument.

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

property current
Reads the current (in Ampere) the dc power supply is putting out.

property current_limit
A floating point property that controls the source current in amps. This is not checked against the allowed range. Depending on whether the instrument is in constant current or constant voltage mode, this might differ from the actual current achieved.

property enabled
A boolean property that controls whether the source is enabled, takes values True or False.

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

property id
Requests and returns the identification of the instrument.

property options
Requests and returns the device options installed.

property power
Reads the power (in Watt) the dc power supply is putting out.

reset()
Resets the instrument.

shutdown()
Disable output, call parent function

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

property voltage
Reads the voltage (in Volt) the dc power supply is putting out.

property voltage_setpoint
A floating point property that controls the source voltage in volts. This is not checked against the allowed range. Depending on whether the instrument is in constant current or constant voltage mode, this might differ from the actual voltage achieved.

7.20.3 Keithley 2400 SourceMeter

class pymeasure.instruments.keithley.**Keithley2400**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 2400 SourceMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2400("GPIB::1")

keithley.apply_current()                # Sets up to source current
keithley.source_current_range = 10e-3   # Sets the source current range to 10 mA
keithley.compliance_voltage = 10        # Sets the compliance voltage to 10 V
keithley.source_current = 0             # Sets the source current to 0 mA
keithley.enable_source()                # Enables the source output

keithley.measure_voltage()              # Sets up to measure voltage

keithley.ramp_to_current(5e-3)          # Ramps the current to 5 mA
print(keithley.voltage)                 # Prints the voltage in Volts

keithley.shutdown()                     # Ramps the current to 0 mA and disables␣
↪output
```

apply_current(*current_range=None*, *compliance_voltage=0.1*)

Configures the instrument to apply a source current, and uses an auto range unless a current range is specified. The compliance voltage is also set.

Parameters

- **compliance_voltage** – A float in the correct range for a *compliance_voltage*
- **current_range** – A *current_range* value or None

apply_voltage(*voltage_range=None*, *compliance_current=0.1*)

Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified. The compliance current is also set.

Parameters

- **compliance_current** – A float in the correct range for a *compliance_current*
- **voltage_range** – A *voltage_range* value or None

property auto_output_off

A boolean property that enables or disables the auto output-off. Valid values are True (output off after measurement) and False (output stays on after measurement).

auto_range_source()

Configures the source to use an automatic range.

property auto_zero

A property that controls the auto zero option. Valid values are True (enabled) and False (disabled) and 'ONCE' (force immediate).

beep(*frequency*, *duration*)

Sounds a system beep.

Parameters

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz

- **duration** – A time in seconds between 0 and 7.9 seconds

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

check_errors()
Logs any system errors reported by the instrument.

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

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

property compliance_voltage
A floating point property that controls the compliance voltage in Volts.

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

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

property current_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property current_range
A floating point property that controls the measurement current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

disable_output_trigger()
Disables the output trigger for the Trigger layer

disable_source()
Disables the source of current or voltage depending on the configuration of the instrument.

property display_enabled
A boolean property that controls whether or not the display of the sourcemeter is enabled. Valid values are True and False.

enable_source()
Enables the source of current or voltage depending on the configuration of the instrument.

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

property filter_count
A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

property filter_state
A string property that controls if the filter is active.

property filter_type
A String property that controls the filter's type. REP : Repeating filter MOV : Moving filter

property id
Requests and returns the identification of the instrument.

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

property line_frequency
An integer property that controls the line frequency in Hertz. Valid values are 50 and 60.

property line_frequency_auto
A boolean property that enables or disables auto line frequency. Valid values are True and False.

property max_current
Returns the maximum current from the buffer

property max_resistance
Returns the maximum resistance from the buffer

property max_voltage
Returns the maximum voltage from the buffer

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

property mean_current
Returns the mean current from the buffer

property mean_resistance
Returns the mean resistance from the buffer

property mean_voltage
Returns the mean voltage from the buffer

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

property measure_concurent_functions
A boolean property that enables or disables the ability to measure more than one function simultaneously. When disabled, volts function is enabled. Valid values are True and False.

measure_current(*nplc=1*, *current=0.000105*, *auto_range=True*)
Configures the measurement of current.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **current** – Upper limit of current in Amps, from -1.05 A to 1.05 A
- **auto_range** – Enables auto_range if True, else uses the set current

measure_resistance(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
Configures the measurement of resistance.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **resistance** – Upper limit of resistance in Ohms, from -210 MOhms to 210 MOhms
- **auto_range** – Enables auto_range if True, else uses the set resistance

measure_voltage(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **voltage** – Upper limit of voltage in Volts, from -210 V to 210 V
- **auto_range** – Enables auto_range if True, else uses the set voltage

property min_current
Returns the minimum current from the buffer

property min_resistance
Returns the minimum resistance from the buffer

property min_voltage
Returns the minimum voltage from the buffer

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

property options
Requests and returns the device options installed.

property output_off_state
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

output_trigger_on_external(*line=1*, *after='DEL'*)
Configures the output trigger on the specified trigger link line number, with the option of supplying the part of the measurement after which the trigger should be generated (default to delay, which is right before the measurement)

Parameters

- **line** – A trigger line from 1 to 4
- **after** – An event string that determines when to trigger

ramp_to_current(*target_current*, *steps=30*, *pause=0.02*)
Ramps to a target current from the set current value over a certain number of linear steps, each separated by a pause duration.

Parameters

- **target_current** – A current in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

ramp_to_voltage(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

Parameters

- **target_voltage** – A voltage in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

reset()
Resets the instrument and clears the queue.

reset_buffer()
Resets the buffer.

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

property resistance_nplc
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property resistance_range
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 210 MOhms. Auto-range is disabled when this property is set.

sample_continuously()
Causes the instrument to continuously read samples and turns off any buffer or output triggering

set_timed_arm(*interval*)
Sets up the measurement to be taken with the internal trigger at a variable sampling rate defined by the interval in seconds between sampling points

set_trigger_counts(*arm*, *trigger*)
Sets the number of counts for both the sweeps (arm) and the points in those sweeps (trigger), where the total number of points can not exceed 2500

shutdown()
Ensures that the current or voltage is turned to zero and disables the output.

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

property source_current_range
A floating point property that controls the source current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

property source_delay
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

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

property source_enabled
A boolean property that controls whether the source is enabled, takes values True or False. The convenience methods *enable_source()* and *disable_source()* can also be used.

property source_mode
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods *apply_current()* and *apply_voltage()* can also be used.

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

property source_voltage_range
A floating point property that controls the source voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

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

start_buffer()
Starts the buffer.

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

property std_current
Returns the current standard deviation from the buffer

property std_resistance
Returns the resistance standard deviation from the buffer

property std_voltage
Returns the voltage standard deviation from the buffer

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

triad(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

Parameters

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

trigger()
Executes a bus trigger, which can be used when *trigger_on_bus()* is configured.

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

property trigger_delay
A floating point property that controls the trigger delay in seconds, which can take values from 0 to 999.9999 s.

trigger_immediately()
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

trigger_on_bus()
Configures the trigger to detect events based on the bus trigger, which can be activated by *trigger()*.

trigger_on_external(*line=1*)
Configures the measurement trigger to be taken from a specific line of an external trigger

Parameters **line** – A trigger line from 1 to 4

use_front_terminals()
Enables the front terminals for measurement, and disables the rear terminals.

use_rear_terminals()
Enables the rear terminals for measurement, and disables the front terminals.

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

property voltage_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property voltage_range
A floating point property that controls the measurement voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

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

7.20.4 Keithley 2450 SourceMeter

class pymeasure.instruments.keithley.**Keithley2450**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 2450 SourceMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2450("GPIB::1")

keithley.apply_current()                # Sets up to source current
keithley.source_current_range = 10e-3   # Sets the source current range to 10 mA
keithley.compliance_voltage = 10        # Sets the compliance voltage to 10 V
keithley.source_current = 0             # Sets the source current to 0 mA
keithley.enable_source()                # Enables the source output

keithley.measure_voltage()              # Sets up to measure voltage

keithley.ramp_to_current(5e-3)          # Ramps the current to 5 mA
print(keithley.voltage)                 # Prints the voltage in Volts

keithley.shutdown()                     # Ramps the current to 0 mA and disables␣
↪output
```

apply_current(*current_range=None*, *compliance_voltage=0.1*)
Configures the instrument to apply a source current, and uses an auto range unless a current range is specified. The compliance voltage is also set.

Parameters

- **compliance_voltage** – A float in the correct range for a *compliance_voltage*

- **current_range** – A *current_range* value or None

apply_voltage(*voltage_range=None*, *compliance_current=0.1*)
Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified. The compliance current is also set.

Parameters

- **compliance_current** – A float in the correct range for a *compliance_current*
- **voltage_range** – A *voltage_range* value or None

auto_range_source()
Configures the source to use an automatic range.

beep(*frequency*, *duration*)
Sounds a system beep.

Parameters

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

check_errors()
Logs any system errors reported by the instrument.

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

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

property compliance_voltage
A floating point property that controls the compliance voltage in Volts.

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

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

property current_filter_count
A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

property current_filter_state
A string property that controls if the filter is active.

property current_filter_type
A String property that controls the filter's type for the current. REP : Repeating filter MOV : Moving filter

property current_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property current_output_off_state
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

property current_range
A floating point property that controls the measurement current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

disable_source()
Disables the source of current or voltage depending on the configuration of the instrument.

enable_source()
Enables the source of current or voltage depending on the configuration of the instrument.

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

property id
Requests and returns the identification of the instrument.

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

property max_current
Returns the maximum current from the buffer

property max_resistance
Returns the maximum resistance from the buffer

property max_voltage
Returns the maximum voltage from the buffer

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

property mean_current
Returns the mean current from the buffer

property mean_resistance
Returns the mean resistance from the buffer

property mean_voltage
Returns the mean voltage from the buffer

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

measure_current(*nplc=1*, *current=0.000105*, *auto_range=True*)
Configures the measurement of current.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **current** – Upper limit of current in Amps, from -1.05 A to 1.05 A
- **auto_range** – Enables auto_range if True, else uses the set current

measure_resistance(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
Configures the measurement of resistance.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **resistance** – Upper limit of resistance in Ohms, from -210 MOhms to 210 MOhms
- **auto_range** – Enables auto_range if True, else uses the set resistance

measure_voltage(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **voltage** – Upper limit of voltage in Volts, from -210 V to 210 V
- **auto_range** – Enables auto_range if True, else uses the set voltage

property min_current
Returns the minimum current from the buffer

property min_resistance
Returns the minimum resistance from the buffer

property min_voltage
Returns the minimum voltage from the buffer

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

property options
Requests and returns the device options installed.

ramp_to_current(*target_current*, *steps=30*, *pause=0.02*)
Ramps to a target current from the set current value over a certain number of linear steps, each separated by a pause duration.

Parameters

- **target_current** – A current in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

ramp_to_voltage(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

Parameters

- **target_voltage** – A voltage in Amps
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

reset()
Resets the instrument and clears the queue.

reset_buffer()
Resets the buffer.

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

property resistance_nplc
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property resistance_range
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 210 MOhms. Auto-range is disabled when this property is set.

shutdown()
Ensures that the current or voltage is turned to zero and disables the output.

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

property source_current_delay
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

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

property source_current_range
A floating point property that controls the source current range in Amps, which can take values between -1.05 and +1.05 A. Auto-range is disabled when this property is set.

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

property source_mode
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods *apply_current()* and *apply_voltage()* can also be used.

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

property source_voltage_delay
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 0 [seconds] and 999.9999 [seconds].

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

property source_voltage_range
A floating point property that controls the source voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

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

start_buffer()
Starts the buffer.

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

property std_current
Returns the current standard deviation from the buffer

property std_resistance
Returns the resistance standard deviation from the buffer

property std_voltage
Returns the voltage standard deviation from the buffer

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

triad(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

Parameters

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

trigger()
Executes a bus trigger.

use_front_terminals()
Enables the front terminals for measurement, and disables the rear terminals.

use_rear_terminals()
Enables the rear terminals for measurement, and disables the front terminals.

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

property voltage_filter_count
A integer property that controls the number of readings that are acquired and stored in the filter buffer for the averaging

property voltage_filter_type
A String property that controls the filter's type for the current. REP : Repeating filter MOV : Moving filter

property voltage_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property voltage_output_off_state
Select the output-off state of the SourceMeter. HIMP : output relay is open, disconnects external circuitry. NORM : V-Source is selected and set to 0V, Compliance is set to 0.5% full scale of the present current range. ZERO : V-Source is selected and set to 0V, compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. GUAR : I-Source is selected and set to 0A

property voltage_range
A floating point property that controls the measurement voltage range in Volts, which can take values from -210 to 210 V. Auto-range is disabled when this property is set.

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the should_stop function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

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

7.20.5 Keithley 2700 MultiMeter/Switch System

class pymeasure.instruments.keithley.**Keithley2700**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 2700 Multimeter/Switch System and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley2700("GPIB::1")
```

beep(*frequency*, *duration*)
Sounds a system beep.

Parameters

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

channels_from_rows_columns(*rows*, *columns*, *slot=None*)
Determine the channel numbers between column(s) and row(s) of the 7709 connection matrix. Returns a list of channel numbers. Only one of the parameters 'rows' or 'columns' can be "all"

Parameters

- **rows** – row number or list of numbers; can also be "all"
- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

check_errors()
Logs any system errors reported by the instrument.

close_rows_to_columns(*rows*, *columns*, *slot=None*)
Closes (connects) the channels between column(s) and row(s) of the 7709 connection matrix. Only one of the parameters 'rows' or 'columns' can be "all"

Parameters

- **rows** – row number or list of numbers; can also be "all"
- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

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

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

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

determine_valid_channels()
Determine what cards are installed into the Keithley 2700 and from that determine what channels are valid.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

display_closed_channels()
Show the presently closed channels on the display of the Keithley 2700.

property display_text
A string property that controls the text shown on the display of the Keithley 2700. Text can be up to 12 ASCII characters and must be enabled to show.

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

get_state_of_channels(*channels*)
Get the open or closed state of the specified channels

Parameters **channels** – a list of channel numbers, or single channel number

property id
Requests and returns the identification of the instrument.

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

open_all_channels()
Open all channels of the Keithley 2700.

property open_channels
A parameter that opens the specified list of channels. Can only be set.

open_rows_to_columns(*rows*, *columns*, *slot=None*)
Opens (disconnects) the channels between column(s) and row(s) of the 7709 connection matrix. Only one of the parameters 'rows' or 'columns' can be "all"

Parameters

- **rows** – row number or list of numbers; can also be "all"

- **columns** – column number or list of numbers; can also be "all"
- **slot** – slot number (1 or 2) of the 7709 card to be used

property options
Property that lists the installed cards in the Keithley 2700. Returns a dict with the integer card numbers on the position.

reset()
Resets the instrument and clears the queue.

reset_buffer()
Resets the buffer.

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

start_buffer()
Starts the buffer.

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

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

property text_enabled
A boolean property that controls whether a text message can be shown on the display of the Keithley 2700.

triad(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

Parameters

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

7.20.6 Keithley 6221 AC and DC Current Source

class pymeasure.instruments.keithley.**Keithley6221**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 6221 AC and DC current source and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley6221("GPIB::1")
keithley.clear()

# Use the keithley as an AC source
keithley.waveform_function = "square"   # Set a square waveform
keithley.waveform_amplitude = 0.05      # Set the amplitude in Amps
keithley.waveform_offset = 0            # Set zero offset
keithley.source_compliance = 10         # Set compliance (limit) in V
keithley.waveform_dutycycle = 50        # Set duty cycle of wave in %
keithley.waveform_frequency = 347       # Set the frequency in Hz
keithley.waveform_ranging = "best"      # Set optimal output ranging
keithley.waveform_duration_cycles = 100 # Set duration of the waveform

# Link end of waveform to Service Request status bit
keithley.operation_event_enabled = 128  # OSB listens to end of wave
keithley.srq_event_enabled = 128        # SRQ listens to OSB

keithley.waveform_arm()                 # Arm (load) the waveform

keithley.waveform_start()               # Start the waveform

keithley.adapter.wait_for_srq()         # Wait for the pulse to finish

keithley.waveform_abort()               # Disarm (unload) the waveform

keithley.shutdown()                     # Disables output
```

beep(*frequency*, *duration*)
Sounds a system beep.

Parameters

- **frequency** – A frequency in Hz between 65 Hz and 2 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

check_errors()
Logs any system errors reported by the instrument.

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

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

define_arbitary_waveform(*datapoints*, *location=1*)
Define the data points for the arbitrary waveform and copy the defined waveform into the given storage location.

Parameters

- **datapoints** – a list (or numpy array) of the data points; all values have to be between -1 and 1; 100 points maximum.
- **location** – integer storage location to store the waveform in. Value must be in range 1 to 4.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

disable_output_trigger()
Disables the output trigger for the Trigger layer

disable_source()
Disables the source of current or voltage depending on the configuration of the instrument.

property display_enabled
A boolean property that controls whether or not the display of the sourcemeter is enabled. Valid values are True and False.

enable_source()
Enables the source of current or voltage depending on the configuration of the instrument.

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

property id
Requests and returns the identification of the instrument.

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

property measurement_event_enabled
An integer value that controls which measurement events are registered in the Measurement Summary Bit (MSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

property measurement_events
An integer value that reads which measurement events have been registered in the Measurement event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

property operation_event_enabled
An integer value that controls which operation events are registered in the Operation Summary Bit (OSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

property operation_events
An integer value that reads which operation events have been registered in the Operation event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

property options
Requests and returns the device options installed.

property output_low_grounded
A boolean property that controls whether the low output of the triax connection is connected to earth ground (True) or is floating (False).

output_trigger_on_external(*line=1*, *after='DEL'*)
Configures the output trigger on the specified trigger link line number, with the option of supplying the part of the measurement after which the trigger should be generated (default to delay, which is right before the measurement)

Parameters

- **line** – A trigger line from 1 to 4
- **after** – An event string that determines when to trigger

property questionable_event_enabled
An integer value that controls which questionable events are registered in the Questionable Summary Bit (QSB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

property questionable_events
An integer value that reads which questionable events have been registered in the Questionable event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

reset()
Resets the instrument and clears the queue.

reset_buffer()
Resets the buffer.

set_timed_arm(*interval*)
Sets up the measurement to be taken with the internal trigger at a variable sampling rate defined by the interval in seconds between sampling points

shutdown()
Disables the output.

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

property source_compliance
A floating point property that controls the compliance of the current source in Volts. valid values are in range 0.1 [V] to 105 [V].

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

property source_delay
A floating point property that sets a manual delay for the source after the output is turned on before a measurement is taken. When this property is set, the auto delay is turned off. Valid values are between 1e-3 [seconds] and 999999.999 [seconds].

property source_enabled
A boolean property that controls whether the source is enabled, takes values True or False. The convenience methods *enable_source()* and *disable_source()* can also be used.

property source_range
A floating point property that controls the source current range in Amps, which can take values between -0.105 A and +0.105 A. Auto-range is disabled when this property is set.

property srq_event_enabled
An integer value that controls which event registers trigger the Service Request (SRQ) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

property standard_event_enabled
An integer value that controls which standard events are registered in the Event Summary Bit (ESB) status bit. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits.

property standard_events
An integer value that reads which standard events have been registered in the Standard event registers. Refer to the Model 6220/6221 Reference Manual for more information about programming the status bits. Reading this value clears the register.

start_buffer()
Starts the buffer.

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

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

triad(*base_frequency*, *duration*)
Sounds a musical triad using the system beep.

Parameters

- **base_frequency** – A frequency in Hz between 65 Hz and 1.3 MHz
- **duration** – A time in seconds between 0 and 7.9 seconds

trigger()
Executes a bus trigger, which can be used when *trigger_on_bus()* is configured.

trigger_immediately()
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

trigger_on_bus()
Configures the trigger to detect events based on the bus trigger, which can be activated by *trigger()*.

trigger_on_external(*line=1*)
Configures the measurement trigger to be taken from a specific line of an external trigger

Parameters **line** – A trigger line from 1 to 4

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

waveform_abort()
Abort the waveform output and disarm the waveform function.

property waveform_amplitude
A floating point property that controls the (peak) amplitude of the waveform in Amps. Valid values are in range 2e-12 to 0.105.

waveform_arm()
Arm the current waveform function.

property waveform_duration_cycles
A floating point property that controls the duration of the waveform in cycles. Valid values are in range 1e-3 to 99999999900.

waveform_duration_set_infinity()
Set the waveform duration to infinity.

property waveform_duration_time
A floating point property that controls the duration of the waveform in seconds. Valid values are in range 100e-9 to 999999.999.

property waveform_dutycycle
A floating point property that controls the duty-cycle of the waveform in percent for the square and ramp waves. Valid values are in range 0 to 100.

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

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

property waveform_offset
A floating point property that controls the offset of the waveform in Amps. Valid values are in range -0.105 to 0.105.

property waveform_ranging
A string property that controls the source ranging of the waveform. Valid values are "best" and "fixed".

waveform_start()
Start the waveform output. Must already be armed

property waveform_use_phasemarker
A boolean property that controls whether the phase marker option is turned on or of. Valid values True (on) or False (off). Other settings for the phase marker have not yet been implemented.

7.20.7 Keithley 6517B Electrometer

class pymeasure.instruments.keithley.**Keithley6517B**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*, pymeasure.instruments.keithley.buffer.KeithleyBuffer

Represents the Keithely 6517B ElectroMeter and provides a high-level interface for interacting with the instrument.

```
keithley = Keithley6517B("GPIB::1")

keithley.apply_voltage()              # Sets up to source current
keithley.source_voltage_range = 200   # Sets the source voltage
                                      # range to 200 V
```

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```
keithley.source_voltage = 20          # Sets the source voltage to 20 V
keithley.enable_source()              # Enables the source output

keithley.measure_resistance()         # Sets up to measure resistance

keithley.ramp_to_voltage(50)          # Ramps the voltage to 50 V
print(keithley.resistance)            # Prints the resistance in Ohms

keithley.shutdown()                   # Ramps the voltage to 0 V
                                      # and disables output
```

apply_voltage(*voltage_range=None*)
Configures the instrument to apply a source voltage, and uses an auto range unless a voltage range is specified.

Parameters **voltage_range** – A *voltage_range* value or None (activates auto range)

auto_range_source()
Configures the source to use an automatic range.

property buffer_data
Returns a numpy array of values from the buffer.

property buffer_points
An integer property that controls the number of buffer points. This does not represent actual points in the buffer, but the configuration value instead.

check_errors()
Logs any system errors reported by the instrument.

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

config_buffer(*points=64*, *delay=0*)
Configures the measurement buffer for a number of points, to be taken with a specified delay.

Parameters

- **points** – The number of points in the buffer.
- **delay** – The delay time in seconds.

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

property current_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC current measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property current_range
A floating point property that controls the measurement current range in Amps, which can take values between -20 and +20 mA. Auto-range is disabled when this property is set.

disable_buffer()
Disables the connection between measurements and the buffer, but does not abort the measurement process.

disable_source()
Disables the source of current or voltage depending on the configuration of the instrument.

enable_source()
Enables the source of current or voltage depending on the configuration of the instrument.

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

property id
Requests and returns the identification of the instrument.

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

measure_current(*nplc=1*, *current=0.000105*, *auto_range=True*)
Configures the measurement of current.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **current** – Upper limit of current in Amps, from -21 mA to 21 mA
- **auto_range** – Enables auto_range if True, else uses the current_range attribut

measure_resistance(*nplc=1*, *resistance=210000.0*, *auto_range=True*)
Configures the measurement of resistance.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **resistance** – Upper limit of resistance in Ohms, from -210 POhms to 210 POhms
- **auto_range** – Enables auto_range if True, else uses the resistance_range attribut

measure_voltage(*nplc=1*, *voltage=21.0*, *auto_range=True*)
Configures the measurement of voltage.

Parameters

- **nplc** – Number of power line cycles (NPLC) from 0.01 to 10
- **voltage** – Upper limit of voltage in Volts, from -1000 V to 1000 V
- **auto_range** – Enables auto_range if True, else uses the voltage_range attribut

property options
Requests and returns the device options installed.

ramp_to_voltage(*target_voltage*, *steps=30*, *pause=0.02*)
Ramps to a target voltage from the set voltage value over a certain number of linear steps, each separated by a pause duration.

Parameters

- **target_voltage** – A voltage in Volts
- **steps** – An integer number of steps
- **pause** – A pause duration in seconds to wait between steps

reset()
Resets the instrument and clears the queue.

reset_buffer()
Resets the buffer.

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

property resistance_nplc
A floating point property that controls the number of power line cycles (NPLC) for the 2-wire resistance measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property resistance_range
A floating point property that controls the resistance range in Ohms, which can take values from 0 to 100e18 Ohms. Auto-range is disabled when this property is set.

shutdown()
Ensures that the current or voltage is turned to zero and disables the output.

property source_current_resistance_limit
Boolean property which enables or disables resistance current limit

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

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

property source_voltage_range
A floating point property that controls the source voltage range in Volts, which can take values from -1000 to 1000 V. Auto-range is disabled when this property is set.

start_buffer()
Starts the buffer.

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

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

trigger()
Executes a bus trigger, which can be used when *trigger_on_bus()* is configured.

trigger_immediately()
Configures measurements to be taken with the internal trigger at the maximum sampling rate.

trigger_on_bus()
Configures the trigger to detect events based on the bus trigger, which can be activated by *trigger()*.

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

property voltage_nplc
A floating point property that controls the number of power line cycles (NPLC) for the DC voltage measurements, which sets the integration period and measurement speed. Takes values from 0.01 to 10, where 0.1, 1, and 10 are Fast, Medium, and Slow respectively.

property voltage_range
A floating point property that controls the measurement voltage range in Volts, which can take values from -1000 to 1000 V. Auto-range is disabled when this property is set.

wait_for_buffer(*should_stop=<function KeithleyBuffer.<lambda>>*, *timeout=60*, *interval=0.1*)
Blocks the program, waiting for a full buffer. This function returns early if the `should_stop` function returns True or the timeout is reached before the buffer is full.

Parameters

- **should_stop** – A function that returns True when this function should return early
- **timeout** – A time in seconds after which this function should return early
- **interval** – A time in seconds for how often to check if the buffer is full

7.20.8 Keithley 2750 Multimeter/Switch System

class pymeasure.instruments.keithley.**Keithley2750**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keithley2750 multimeter/switch system and provides a high-level interface for interacting with the instrument.

check_errors()
Read all errors from the instrument.

Returns list of error entries

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

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

Returns None

property closed_channels
Reads the list of closed channels

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

property id
Requests and returns the identification of the instrument.

open(*channel*)
Opens (disconnects) the specified channel.

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

Returns None

open_all()
Opens (disconnects) all the channels on the switch matrix.

Returns None

property options
Requests and returns the device options installed.

reset()
Resets the instrument.

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

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

7.20.9 Keithley 2600 SourceMeter

class pymeasure.instruments.keithley.**Keithley2600**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keithley 2600 series (channel A and B) SourceMeter

check_errors()
Logs any system errors reported by the instrument.

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

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

property id
Requests and returns the identification of the instrument.

property options
Requests and returns the device options installed.

reset()
Resets the instrument.

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

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

7.21 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*.

7.21.1 Keysight DSOX1102G Oscilloscope

class pymeasure.instruments.keysight.**KeysightDSOX1102G**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keysight DSOX1102G Oscilloscope interface for interacting with the instrument.

Refer to the Keysight DSOX1102G Oscilloscope Programmer's Guide for further details about using the lower-level methods to interact directly with the scope.

```
scope = KeysightDSOX1102G(resource)
scope.autoscale()
ch1_data_array, ch1_preamble = scope.download_data(source="channel1", points=2000)
# ...
scope.shutdown()
```

Known issues:

- The digitize command will be completed before the operation is. May lead to VI_ERROR_TMO (timeout) occuring when sending commands immediately after digitize. Current fix: if deemed necessary, add delay between digitize and follow-up command to scope.

property acquisition_mode
A string parameter that sets the acquisition mode. Can be "realtime" or "segmented".

property acquisition_type
A string parameter that sets the type of data acquisition. Can be "normal", "average", "hresolution", or "peak".

ask(*command*)
Writes the command to the instrument through the adapter and returns the read response.

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

autoscale()
Autoscale displayed channels.

check_errors()
Read all errors from the instrument.

Returns list of error entries

clear()
Clears the instrument status byte

clear_status()
Clear device status.

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

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

default_setup()
Default setup, some user settings (like preferences) remain unchanged.

digitize(*source: str*)
Acquire waveforms according to the settings of the :ACQuire commands. Ensure a delay between the digitize operation and further commands, as timeout may be reached before digitize has completed. :param source: "channel1", "channel2", "function", "math", "fft", "abus", or "ext".

download_data(*source*, *points=62500*)
Get data from specified source of oscilloscope. Returned objects are a np.ndarray of data values (no temporal axis) and a dict of the waveform preamble, which can be used to build the corresponding time values for all data points.

Multimeter will be stopped for proper acquisition.

Parameters

- **source** – measurement source, can be "channel1", "channel2", "function", "fft", "wmemory1", "wmemory2", or "ext".
- **points** – integer number of points to acquire. Note that oscilloscope may return less points than specified, this is not an issue of this library. Can be 100, 250, 500, 1000, 2000, 5000, 10000, 20000, 50000, or 62500.

Return data_ndarray, waveform_preamble_dict see waveform_preamble property for dict format.

download_image(*format_='png'*, *color_palette='color'*)
Get image of oscilloscope screen in bytearray of specified file format.

Parameters

- **format** – "bmp", "bmp8bit", or "png"
- **color_palette** – "color" or "grayscale"

factory_reset()
Factory default setup, no user settings remain unchanged.

property id
Requests and returns the identification of the instrument.

static measurement(*get_command*, *docs*, *values=()*, *map_values=None*, *get_process=<function Instrument.<lambda>>*, *command_process=<function Instrument.<lambda>>*, *check_get_errors=False*, ***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

property options
Requests and returns the device options installed.

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

reset()
Resets the instrument.

run()
Starts repetitive acquisitions. This is the same as pressing the Run key on the front panel.

static setting(*set_command*, *docs*, *validator=<function Instrument.<lambda>>*, *values=()*, *map_values=False*, *set_process=<function Instrument.<lambda>>*, *check_set_errors=False*, ***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

single()
Causes the instrument to acquire a single trigger of data. This is the same as pressing the Single key on the front panel.

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

stop()
Stops the acquisition. This is the same as pressing the Stop key on the front panel.

property system_setup
A string parameter that sets up the oscilloscope. Must be in IEEE 488.2 format. It is recommended to only set a string previously obtained from this command.

property timebase
Read timebase setup as a dict containing the following keys: - "REF": position on screen of timebase

reference (str) - “MAIN:RANG”: full-scale timebase range (float) - “POS”: interval between trigger and reference point (float) - “MODE”: mode (str)

property timebase_mode
A string parameter that sets the current time base. Can be “main”, “window”, “xy”, or “roll”.

property timebase_offset
A float parameter that sets the time interval in seconds between the trigger event and the reference position (at center of screen by default).

property timebase_range
A float parameter that sets the full-scale horizontal time in seconds for the main window.

property timebase_scale
A float parameter that sets the horizontal scale (units per division) in seconds for the main window.

timebase_setup(*mode=None*, *offset=None*, *horizontal_range=None*, *scale=None*)
Set up timebase. Unspecified parameters are not modified. Modifying a single parameter might impact other parameters. Refer to oscilloscope documentation and make multiple consecutive calls to channel_setup if needed.

Parameters

- **mode** – Timebase mode, can be “main”, “window”, “xy”, or “roll”.
- **offset** – Offset in seconds between trigger and center of screen.
- **horizontal_range** – Full-scale range in seconds.
- **scale** – Units-per-division in seconds.

values(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any key-word arguments.

property waveform_data
Get the binary block of sampled data points transmitted using the IEEE 488.2 arbitrary block data format.

property waveform_format
A string parameter that controls how the data is formatted when sent from the oscilloscope. Can be “ascii”, “word” or “byte”. Words are transmitted in big endian by default.

property waveform_points
An integer parameter that sets the number of waveform points to be transferred with the waveform_data method. Can be any of the following values: 100, 250, 500, 1000, 2 000, 5 000, 10 000, 20 000, 50 000, 62 500.

Note that the oscilloscope may provide less than the specified nb of points.

property waveform_points_mode
A string parameter that sets the data record to be transferred with the waveform_data method. Can be “normal”, “maximum”, or “raw”.

property waveform_preamble
Get preamble information for the selected waveform source as a dict with the following keys: - “format”: byte, word, or ascii (str) - “type”: normal, peak detect, or average (str) - “points”: nb of data points transferred (int) - “count”: always 1 (int) - “xincrement”: time difference between data points (float) - “xorigin”: first data point in memory (float) - “xreference”: data point associated with xorigin (int) - “yincrement”: voltage difference between data points (float) - “yorigin”: voltage at center of screen (float) - “yreference”: data point associated with yorigin (int)

property waveform_source
A string parameter that selects the analog channel, function, or reference waveform to be used as the source

for the waveform methods. Can be “channel1”, “channel2”, “function”, “fft”, “wmemory1”, “wmemory2”, or “ext”.

write(*command*)
Writes the command to the instrument through the adapter.

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

7.21.2 Keysight N5767A Power Supply

class pymeasure.instruments.keysight.**KeysightN5767A**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Keysight N5767A Power supply interface for interacting with the instrument.

check_errors()
Read all errors from the instrument.

Returns list of error entries

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

property current
Reads a setting current in Amps.

property current_range
A floating point property that controls the DC current range in Amps, which can take values from 0 to 25 A. Auto-range is disabled when this property is set.

disable()
Disables the flow of current.

enable()
Enables the flow of current.

property id
Requests and returns the identification of the instrument.

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

property options
Requests and returns the device options installed.

reset()
Resets the instrument.

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

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

property voltage
Reads a DC voltage measurement in Volts.

property voltage_range
A floating point property that controls the DC voltage range in Volts, which can take values from 0 to 60 V. Auto-range is disabled when this property is set.

7.22 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*.

7.22.1 Lake Shore Adapters

class pymeasure.instruments.lakeshore.LakeShoreUSBAdapter(*port*)
Bases: *pymeasure.adapters.serial.SerialAdapter*

Provides a SerialAdapter with the specific baudrate, timeout, parity, and byte size for LakeShore USB communication.

Initiates the adapter to open serial communcation over the supplied port.

Parameters **port** – A string representing the serial port

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

Parameters

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

Returns binary string.

Return type bytes

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

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

Returns String ASCII response of the instrument

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

Parameters

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

Returns NumPy array of values

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

Returns String ASCII response of the instrument.

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

Parameters

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

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

write(*command*)
Overwrites the *SerialAdapter.write* method to automatically append a Unix-style linebreak at the end of the command.

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

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

Parameters

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

Returns number of bytes written

7.22.2 Lake Shore 331 Temperature Controller

class pymeasure.instruments.lakeshore.**LakeShore331**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Lake Shore 331 Temperature Controller and provides a high-level interface for interacting with the instrument.

```
controller = LakeShore331("GPIB::1")

print(controller.setpoint_1)        # Print the current setpoint for loop 1
controller.setpoint_1 = 50          # Change the setpoint to 50 K
controller.heater_range = 'low'     # Change the heater range to Low
controller.wait_for_temperature()   # Wait for the temperature to stabilize
print(controller.temperature_A)     # Print the temperature at sensor A
```

disable_heater()
Turns the *heater_range* to `off` to disable the heater.

property heater_range
A string property that controls the heater range, which can take the values: off, low, medium, and high. These values correlate to 0, 0.5, 5 and 50 W respectively.

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

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

property temperature_A
Reads the temperature of the sensor A in Kelvin.

property temperature_B
Reads the temperature of the sensor B in Kelvin.

wait_for_temperature(*accuracy=0.1*, *interval=0.1*, *sensor='A'*, *setpoint=1*, *timeout=360*, *should_stop=<function LakeShore331.<lambda>>*)
Blocks the program, waiting for the temperature to reach the setpoint within the accuracy (%), checking this each interval time in seconds.

Parameters

- **accuracy** – An acceptable percentage deviation between the setpoint and temperature
- **interval** – A time in seconds that controls the refresh rate
- **sensor** – The desired sensor to read, either A or B
- **setpoint** – The desired setpoint loop to read, either 1 or 2
- **timeout** – A timeout in seconds after which an exception is raised
- **should_stop** – A function that returns True if waiting should stop, by default this always returns False

7.22.3 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

property field
Returns the field in the current units

measure(*points*, *has_aborted=<function LakeShore425.<lambda>>*, *delay=0.001*)
Returns the mean and standard deviation of a given number of points while blocking

property range
A floating point property that controls the field range in units of Gauss, which can take the values 35, 350, 3500, and 35,000 G.

property unit
A string property that controls the units of the instrument, which can take the values of G, T, Oe, or A/m.

zero_probe()
Initiates the zero field sequence to calibrate the probe

7.23 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*.

7.23.1 ESP 300 Motion Controller

class pymeasure.instruments.newport.**ESP300**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Newport ESP 300 Motion Controller and provides a high-level for interacting with the instrument.

By default this instrument is constructed with x, y, and phi attributes that represent axes 1, 2, and 3. Custom implementations can overwrite this depending on the avalible axes. Axes are controlled through an *Axis* class.

property axes
A list of the *Axis* objects that are present.

clear_errors()
Clears the error messages by checking until a 0 code is recived.

disable()
Disables all of the axes associated with this controller.

enable()
Enables all of the axes associated with this controller.

property error
Reads an error code from the motion controller.

property errors
Returns a list of error Exceptions that can be later raised, or used to diagnose the situation.

shutdown()
Shuts down the controller by disabling all of the axes.

class pymeasure.instruments.newport.esp300.**Axis**(*axis*, *controller*)
Bases: object

Represents an axis of the Newport ESP300 Motor Controller, which can have independent parameters from the other axes.

define_position(*position*)
Overwrites the value of the current position with the given value.

disable()
Disables motion for the axis.

enable()
Enables motion for the axis.

property enabled
Returns a boolean value that is True if the motion for this axis is enabled.

home(*type=1*)
Drives the axis to the home position, which may be the negative hardware limit for some actuators (e.g. LTA-HS). type can take integer values from 0 to 6.

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

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

property position
A floating point property that controls the position of the axis. The units are defined based on the actuator. Use the *wait_for_stop()* method to ensure the position is stable.

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

property units
A string property that controls the displacement units of the axis, which can take values of: enconder count, motor step, millimeter, micrometer, inches, milli-inches, micro-inches, degree, gradient, radian, milliradian, and microradian.

wait_for_stop(*delay=0*, *interval=0.05*)
Blocks the program until the motion is completed. A further delay can be specified in seconds.

zero()
Resets the axis position to be zero at the current poisiton.

class pymeasure.instruments.newport.esp300.**AxisError**(*code*)
Bases: Exception

Raised when a particular axis causes an error for the Newport ESP300.

class pymeasure.instruments.newport.esp300.**GeneralError**(*code*)
Bases: Exception

Raised when the Newport ESP300 has a general error.

7.24 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*.

7.24.1 NI Virtual Bench

General Information

The armstrap/pyvirtualbench Python wrapper for the VirtualBench C-API is required. This Instrument driver only interfaces the pyvirtualbench Python wrapper.

Examples

To be documented. Check the examples in the pyvirtualbench repository to get an idea.

Simple Example to switch digital lines of the DIO module.

```
from pymeasure.instruments.ni import VirtualBench

vb = VirtualBench(device_name='VB8012-3057E1C')
line = 'dig/2'  # may be list of lines
# initialize DIO module -> available via vb.dio
vb.acquire_digital_input_output(line, reset=False)

vb.dio.write(self.line, {True})
sleep(1000)
vb.dio.write(self.line, {False})

vb.shutdown()
```

Instrument Class

class pymeasure.instruments.ni.virtualbench.**VirtualBench**(*device_name=''*, *name='VirtualBench'*)

Bases: object

Represents National Instruments Virtual Bench main frame.

Subclasses implement the functionalities of the different modules:

- Mixed-Signal-Oscilloscope (MSO)
- Digital Input Output (DIO)
- Function Generator (FGEN)
- Power Supply (PS)
- Serial Peripheral Interface (SPI) -> not implemented for pymeasure yet
- Inter Integrated Circuit (I2C) -> not implemented for pymeasure yet

For every module exist methods to save/load the configuration to file. These methods are not wrapped so far, checkout the pyvirtualbench file.

All calibration methods and classes are not wrapped so far, since these are not required on a very regular basis. Also the connections via network are not yet implemented. Check the pyvirtualbench file, if you need the functionality.

Parameters

- **device_name** (*str*) – Full unique device name
- **name** (*str*) – Name for display in pymeasure

class DigitalInputOutput(*virtualbench*, *lines*, *reset*, *vb_name=''*)

Bases: pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument

Represents Digital Input Output (DIO) Module of Virtual Bench device. Allows to read/write digital channels and/or set channels to export the start signal of FGEN module or trigger of MSO module.

export_signal(*line*, *digitalSignalSource*)

Exports a signal to the specified line.

Parameters

- **line** (*str*) – Line string
- **digitalSignalSource** (*int*) – 0 for FGEN start or 1 for MSO trigger

query_export_signal(*line*)

Indicates the signal being exported on the specified line.

Parameters **line** (*str*) – Line string

Returns Exported signal (FGEN start or MSO trigger)

Return type enum

query_line_configuration()

Indicates the current line configurations. Tristate Lines, Static Lines, and Export Lines contain comma-separated range_data and/or colon-delimited lists of all acquired lines

read(*lines*)

Reads the current state of the specified lines.

Parameters **lines** (*str*) – Line string, requires full name specification e.g. 'VB8012-xxxxxxx/dig/0:7' since instrument_handle is not required (only library_handle)

Returns List of line states (HIGH/LOW)

Return type list

reset_instrument()

Resets the session configuration to default values, and resets the device and driver software to a known state.

shutdown()

Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

tristate_lines(*lines*)

Sets all specified lines to a high-impedance state. (Default)

validate_lines(*lines*, *return_single_lines=False*, *validate_init=False*)

Validate lines string Allowed patterns (case sensitive):

- 'VBxxxx-xxxxxxx/dig/0:7'
- 'VBxxxx-xxxxxxx/dig/0'
- 'dig/0'
- 'VBxxxx-xxxxxxx/trig'
- 'trig'

Allowed Line Numbers: 0-7 or trig

Parameters

- **lines** (*str*) – Line string to test
- **return_single_lines** (*bool, optional*) – Return list of line numbers as well, defaults to False
- **validate_init** (*bool, optional*) – Check if lines are initialized (in self._line_numbers), defaults to False

Returns Line string, optional list of single line numbers

Return type str, optional (str, list)

write(*lines*, *data*)
Writes data to the specified lines.

Parameters
- **lines** (*str*) – Line string
- **data** (*list or tuple*) – List of data, (True = High, False = Low)

class DigitalMultimeter(*virtualbench*, *reset*, *vb_name=''*)
Bases: pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument

Represents Digital Multimeter (DMM) Module of Virtual Bench device. Allows to measure either DC/AC voltage or current, Resistance or Diodes.

configure_ac_current(*auto_range_terminal*)
Configure auto rage terminal for AC current measurement

Parameters auto_range_terminal – Terminal to perform auto ranging ('LOW' or 'HIGH')

configure_dc_current(*auto_range_terminal*)
Configure auto rage terminal for DC current measurement

Parameters auto_range_terminal – Terminal to perform auto ranging ('LOW' or 'HIGH')

configure_dc_voltage(*dmm_input_resistance*)
Configure DC voltage input resistance

Parameters dmm_input_resistance(*int or str*) – Input resistance ('TEN_MEGA_OHM' or 'TEN_GIGA_OHM')

configure_measurement(*dmm_function*, *auto_range=True*, *manual_range=1.0*)
Configure Instrument to take a DMM measurement

Parameters
- **function index or name** (*dmm_function:DMM*) –
  - 'DC_VOLTS', 'AC_VOLTS'
  - 'DC_CURRENT', 'AC_CURRENT'
  - 'RESISTANCE'
  - 'DIODE'
- **auto_range** (*bool*) – Enable/Disable auto ranging
- **manual_range** (*float*) – Manually set measurement range

query_ac_current()
Indicates auto range terminal for AC current measurement

query_dc_current()
Indicates auto range terminal for DC current measurement

query_dc_voltage()
Indicates input resistance setting for DC voltage measurement

query_measurement()
Query DMM measurement settings from the instrument

Returns Auto range, range data

Return type (bool, float)

read()
Read measurement value from the instrument

Returns Measurement value

Return type float

reset_instrument()
Reset the DMM module to defaults

shutdown()
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

validate_auto_range_terminal(*auto_range_terminal*)
Check value for choosing the auto range terminal for DC current measurement

Parameters **auto_range_terminal** (*int or str*) – Terminal to perform auto ranging ('LOW' or 'HIGH')

Returns Auto range terminal to pass to the instrument

Return type int

validate_dmm_function(*dmm_function*)
Check if DMM function *dmm_function* exists

Parameters **dmm_function** (*int or str*) – DMM function index or name:

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

Returns DMM function index to pass to the instrument

Return type int

static validate_range(*dmm_function*, *range*)
Checks if range is valid for the chosen dmm_function

Parameters

- **dmm_function** (*int*) – DMM Function
- **range** (*int or float*) – Range value, e.g. maximum value to measure

Returns Range value to pass to instrument

Return type int

class FunctionGenerator(*virtualbench*, *reset*, *vb_name=''*)
Bases: pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument

Represents Function Generator (FGEN) Module of Virtual Bench device.

configure_arbitrary_waveform(*waveform*, *sample_period*)
Configures the instrument to output a waveform. The waveform is output either after the end of the current waveform if output is enabled, or immediately after output is enabled.

Parameters

- **waveform** (*list*) – Waveform as list of values
- **sample_period** (*float*) – Time between two waveform points (maximum of 125MS/s, which equals 80ns)

configure_arbitrary_waveform_gain_and_offset(*gain*, *dc_offset*)
Configures the instrument to output an arbitrary waveform with a specified gain and offset value. The waveform is output either after the end of the current waveform if output is enabled, or immediately after output is enabled.

Parameters

- **gain** (*float*) – Gain, multiplier of waveform values
- **dc_offset** (*float*) – DC offset in volts

configure_standard_waveform(*waveform_function*, *amplitude*, *dc_offset*, *frequency*, *duty_cycle*)
Configures the instrument to output a standard waveform. Check instrument manual for maximum ratings which depend on load.

Parameters

- **waveform_function** (*int or str*) – Waveform function ("SINE", "SQUARE", "TRIANGLE/RAMP", "DC")
- **amplitude** (*float*) – Amplitude in volts
- **dc_offset** (*float*) – DC offset in volts
- **frequency** (*float*) – Frequency in Hz
- **duty_cycle** (*int*) – Duty cycle in %

property filter
Enables or disables the filter on the instrument.

Parameters **enable_filter** (*bool*) – Enable/Disable filter

query_arbitrary_waveform()
Returns the samples per second for arbitrary waveform generation.

Returns Samples per second

Return type int

query_arbitrary_waveform_gain_and_offset()
Returns the settings for arbitrary waveform generation that includes gain and offset settings.

Returns Gain, DC offset

Return type (float, float)

query_generation_status()
Returns the status of waveform generation on the instrument.

Returns Status

Return type enum

query_standard_waveform()
Returns the settings for a standard waveform generation.

Returns Waveform function, amplitude, dc_offset, frequency, duty_cycle

Return type (enum, float, float, float, int)

query_waveform_mode()
Indicates whether the waveform output by the instrument is a standard or arbitrary waveform.

Returns Waveform mode

Return type enum

reset_instrument()
Resets the session configuration to default values, and resets the device and driver software to a known state.

run()
Transitions the session from the Stopped state to the Running state.

self_calibrate()
Performs offset nulling calibration on the device. You must run FGEN Initialize prior to running this method.

shutdown()
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

stop()
Transitions the acquisition from either the Triggered or Running state to the Stopped state.

class MixedSignalOscilloscope(*virtualbench*, *reset*, *vb_name=''*)
Bases: pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument

Represents Mixed Signal Oscilloscope (MSO) Module of Virtual Bench device. Allows to measure oscilloscope data from analog and digital channels.

Methods from pyvirtualbench not implemented in pymeasure yet:

- enable_digital_channels
- configure_digital_threshold
- configure_advanced_digital_timing
- configure_state_mode
- configure_digital_edge_trigger
- configure_digital_pattern_trigger
- configure_digital_glitch_trigger
- configure_digital_pulse_width_trigger
- query_digital_channel
- query_enabled_digital_channels
- query_digital_threshold
- query_advanced_digital_timing
- query_state_mode
- query_digital_edge_trigger
- query_digital_pattern_trigger
- query_digital_glitch_trigger
- query_digital_pulse_width_trigger
- read_digital_u64

auto_setup()
Automatically configure the instrument

configure_analog_channel(*channel*, *enable_channel*, *vertical_range*, *vertical_offset*, *probe_attenuation*, *vertical_coupling*)
Configure analog measurement channel

Parameters

- **channel** (*str*) – Channel string

- **enable_channel** (*bool*) – Enable/Disable channel
- **vertical_range** (*float*) – Vertical measurement range (0V - 20V), the instrument discretizes to these ranges: `[20, 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05]` which are 5x the values shown in the native UI.
- **vertical_offset** (*float*) – Vertical offset to correct for (inverted compared to VB native UI, -20V - +20V, resolution 0.1mV)
- **probe_attenuation** (*int or str*) – Probe attenuation (`'ATTENUATION_10X'` or `'ATTENUATION_1X'`)
- **vertical_coupling** (*int or str*) – Vertical coupling (`'AC'` or `'DC'`)

configure_analog_channel_characteristics(*channel*, *input_impedance*, *bandwidth_limit*)

Configure electrical characteristics of the specified channel

Parameters

- **channel** (*str*) – Channel string
- **input_impedance** (*int or str*) – Input Impedance (`'ONE_MEGA_OHM'` or `'FIFTY_OHMS'`)
- **bandwidth_limit** (*int*) – Bandwidth limit (100MHz or 20MHz)

configure_analog_edge_trigger(*trigger_source*, *trigger_slope*, *trigger_level*, *trigger_hysteresis*, *trigger_instance*)

Configures a trigger to activate on the specified source when the analog edge reaches the specified levels.

Parameters

- **trigger_source** (*str*) – Channel string
- **trigger_slope** (*int or str*) – Trigger slope (`'RISING'`, `'FALLING'` or `'EITHER'`)
- **trigger_level** (*float*) – Trigger level
- **trigger_hysteresis** (*float*) – Trigger hysteresis
- **trigger_instance** (*int or str*) – Trigger instance

configure_analog_pulse_width_trigger(*trigger_source*, *trigger_polarity*, *trigger_level*, *comparison_mode*, *lower_limit*, *upper_limit*, *trigger_instance*)

Configures a trigger to activate on the specified source when the analog edge reaches the specified levels within a specified window of time.

Parameters

- **trigger_source** (*str*) – Channel string
- **trigger_polarity** (*int or str*) – Trigger slope (`'POSITIVE'` or `'NEGATIVE'`)
- **trigger_level** (*float*) – Trigger level
- **comparison_mode** (*int or str*) – Mode of compariosn (`'GREATER_THAN_UPPER_LIMIT'`, `'LESS_THAN_LOWER_LIMIT'`, `'INSIDE_LIMITS'` or `'OUTSIDE_LIMITS'`)
- **lower_limit** (*float*) – Lower limit
- **upper_limit** (*float*) – Upper limit

- **trigger_instance** (*int or str*) – Trigger instance

configure_immediate_trigger()
Configures a trigger to immediately activate on the specified channels after the pretrigger time has expired.

configure_timing(*sample_rate*, *acquisition_time*, *pretrigger_time*, *sampling_mode*)
Configure timing settings of the MSO

Parameters

- **sample_rate** (*int*) – Sample rate (15.26kS - 1GS)
- **acquisition_time** (*float*) – Acquisition time (1ns - 68.711s)
- **pretrigger_time** (*float*) – Pretrigger time (0s - 10s)
- **sampling_mode** – Sampling mode ('SAMPLE' or 'PEAK_DETECT')

configure_trigger_delay(*trigger_delay*)
Configures the amount of time to wait after a trigger condition is met before triggering.

param float trigger_delay Trigger delay (0s - 17.1799s)

force_trigger()
Causes a software-timed trigger to occur after the pretrigger time has expired.

query_acquisition_status()
Returns the status of a completed or ongoing acquisition.

query_analog_channel(*channel*)
Indicates the vertical configuration of the specified channel.

Returns Channel enabled, vertical range, vertical offset, probe attenuation, vertical coupling

Return type (bool, float, float, enum, enum)

query_analog_channel_characteristics(*channel*)
Indicates the properties that control the electrical characteristics of the specified channel. This method returns an error if too much power is applied to the channel.

return Input impedance, bandwidth limit

rtype (enum, float)

query_analog_edge_trigger(*trigger_instance*)
Indicates the analog edge trigger configuration of the specified instance.

Returns Trigger source, trigger slope, trigger level, trigger hysteresis

Return type (str, enum, float, float)

query_analog_pulse_width_trigger(*trigger_instance*)
Indicates the analog pulse width trigger configuration of the specified instance.

Returns Trigger source, trigger polarity, trigger level, comparison mode, lower limit, upper limit

Return type (str, enum, float, enum, float, float)

query_enabled_analog_channels()
Returns String of enabled analog channels.

Returns Enabled analog channels

Return type str

query_timing()
Indicates the timing configuration of the MSO. Call directly before measurement to read the actual timing configuration and write it to the corresponding class variables. Necessary to interpret the measurement data, since it contains no time information.

Returns Sample rate, acquisition time, pretrigger time, sampling mode

Return type (float, float, float, enum)

query_trigger_delay()
Indicates the trigger delay setting of the MSO.

Returns Trigger delay

Return type float

query_trigger_type(*trigger_instance*)
Indicates the trigger type of the specified instance.

Parameters **trigger_instance** – Trigger instance (`'A'` or `'B'`)

Returns Trigger type

Return type str

read_analog_digital_dataframe()
Transfers data from the instrument and returns a pandas dataframe of the analog measurement data, including time coordinates

Returns Dataframe with time and measurement data

Return type pd.DataFrame

read_analog_digital_u64()
Transfers data from the instrument as long as the acquisition state is Acquisition Complete. If the state is either Running or Triggered, this method will wait until the state transitions to Acquisition Complete. If the state is Stopped, this method returns an error.

Returns Analog data out, analog data stride, analog t0, digital data out, digital timestamps out, digital t0, trigger timestamp, trigger reason

Return type (list, int, pyvb.Timestamp, list, list, pyvb.Timestamp, pyvb.Timestamp, enum)

reset_instrument()
Resets the session configuration to default values, and resets the device and driver software to a known state.

run(*autoTrigger=True*)
Transitions the acquisition from the Stopped state to the Running state. If the current state is Triggered, the acquisition is first transitioned to the Stopped state before transitioning to the Running state. This method returns an error if too much power is applied to any enabled channel.

Parameters **autoTrigger** (*bool*) – Enable/Disable auto triggering

shutdown()
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

stop()
Transitions the acquisition from either the Triggered or Running state to the Stopped state.

validate_channel(*channel*)
Check if `channel` is a correct specification

Parameters **channel** (*str*) – Channel string

Returns Channel string

Return type str

static validate_trigger_instance(*trigger_instance*)
Check if trigger_instance is a valid choice

Parameters **trigger_instance** (*int or str*) – Trigger instance ('A' or 'B')

Returns Trigger instance

Return type int

class PowerSupply(*virtualbench*, *reset*, *vb_name=''*)
Bases: pymeasure.instruments.ni.virtualbench.VirtualBench.VirtualBenchInstrument

Represents Power Supply (PS) Module of Virtual Bench device

configure_current_output(*channel*, *current_level*, *voltage_limit*)
Configures a current output on the specified channel. This method should be called once for every channel you want to configure to output current.

configure_voltage_output(*channel*, *voltage_level*, *current_limit*)
Configures a voltage output on the specified channel. This method should be called once for every channel you want to configure to output voltage.

property outputs_enabled
Enables or disables all outputs on all channels of the instrument.

Parameters **enable_outputs** (*bool*) – Enable/Disable outputs

query_current_output(*channel*)
Indicates the current output settings on the specified channel.

query_voltage_output(*channel*)
Indicates the voltage output settings on the specified channel.

read_output(*channel*)
Reads the voltage and current levels and outout mode of the specified channel.

reset_instrument()
Resets the session configuration to default values, and resets the device and driver software to a known state.

shutdown()
Removes the session and deallocates any resources acquired during the session. If output is enabled on any channels, they remain in their current state.

property tracking
Enables or disables tracking between the positive and negative 25V channels. If enabled, any configuration change on the positive 25V channel is mirrored to the negative 25V channel, and any writes to the negative 25V channel are ignored.

Parameters **enable_tracking** (*bool*) – Enable/Disable tracking

validate_channel(*channel*, *current=False*, *voltage=False*)
Check if channel string is valid and if output current/voltage are within the output ranges of the channel

Parameters

- **channel** (*str*) – Channel string ("ps/+6V","ps/+25V","ps/-25V")

- **current** (*bool, optional*) – Current output, defaults to False
- **voltage** (*bool, optional*) – Voltage output, defaults to False

Returns channel or channel, current & voltage

Return type str or (str, float, float)

acquire_digital_input_output(*lines*, *reset=False*)
Establishes communication with the DIO module. This method should be called once per session.

Parameters

- **lines** (*str*) – Lines to acquire, reading is possible on all lines
- **reset** (*bool, optional*) – Reset DIO module, defaults to False

acquire_digital_multimeter(*reset=False*)
Establishes communication with the DMM module. This method should be called once per session.

Parameters **reset** (*bool, optional*) – Reset the DMM module, defaults to False

acquire_function_generator(*reset=False*)
Establishes communication with the FGEN module. This method should be called once per session.

Parameters **reset** (*bool, optional*) – Reset the FGEN module, defaults to False

acquire_mixed_signal_oscilloscope(*reset=False*)
Establishes communication with the MSO module. This method should be called once per session.

Parameters **reset** (*bool, optional*) – Reset the MSO module, defaults to False

acquire_power_supply(*reset=False*)
Establishes communication with the PS module. This method should be called once per session.

Parameters **reset** (*bool, optional*) – Reset the PS module, defaults to False

collapse_channel_string(*names_in*)
Collapses a channel string into a comma and colon-delimited equivalent. Last element is the number of channels.

Parameters **names_in** (*str*) – Channel string

Returns Channel string with colon notation where possible, number of channels

Return type (str, int)

convert_timestamp_to_values(*timestamp*)
Converts a timestamp to seconds and fractional seconds

Parameters **timestamp** (*pyvb.Timestamp*) – VirtualBench timestamp

Returns (seconds_since_1970, fractional seconds)

Return type (int, float)

convert_values_to_datetime(*timestamp*)
Converts timestamp to datetime object

Parameters **timestamp** (*pyvb.Timestamp*) – VirtualBench timestamp

Returns Timestamp as DateTime object

Return type DateTime

convert_values_to_timestamp(*seconds_since_1970*, *fractional_seconds*)
Converts seconds and fractional seconds to a timestamp

Parameters

- **seconds_since_1970** (*int*) – Date/Time in seconds since 1970
- **fractional_seconds** (*float*) – Fractional seconds

Returns VirtualBench timestamp

Return type pyvb.Timestamp

expand_channel_string(*names_in*)
Expands a channel string into a comma-delimited (no colon) equivalent. Last element is the number of channels. `'dig/0:2'` -> `('dig/0, dig/1, dig/2',3)`

Parameters **names_in** (*str*) – Channel string

Returns Channel string with all channels separated by comma, number of channels

Return type (str, int)

get_calibration_information()
Returns calibration information for the specified device, including the last calibration date and calibration interval.

Returns Calibration date, recommended calibration interval in months, calibration interval in months

Return type (pyvb.Timestamp, int, int)

get_library_version()
Return the version of the VirtualBench runtime library

shutdown()
Finalize the VirtualBench library.

class pymeasure.instruments.ni.virtualbench.**VirtualBench_Direct**(**args: Any*, ***kwargs: Any*)
Bases: pyvirtualbench.

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

7.25 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*.

7.25.1 Oxford Instruments Intelligent Temperature Controller 503

class pymeasure.instruments.oxfordinstruments.**ITC503**(*resourceName*, *clear_buffer=True*, *max_temperature=301*, *min_temperature=0*, ***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
```

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```
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
```

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

property 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.

property gasflow
A floating point property that controls gas flow when in manual mode. The value is expressed as a percentage of the maximum gas flow. Valid values are in range 0 [off] to 99.9 [%].

property heater
A floating point property that sets the required heater output when in manual mode. The parameter is expressed as a percentage of the maximum voltage. Valid values are in range 0 [off] to 99.9 [%].

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

property 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.

property 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.

property temperature_1
Reads the temperature of the sensor 1 in Kelvin.

property temperature_2
Reads the temperature of the sensor 2 in Kelvin.

property temperature_3
Reads the temperature of the sensor 3 in Kelvin.

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

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

wait_for_temperature(*error=0.01*, *timeout=3600*, *check_interval=0.5*, *stability_interval=10*, *thermalize_interval=300*, *should_stop=<function ITC503.<lambda>>*, *max_comm_errors=None*)
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.
- **max_comm_errors** – The maximum number of communication errors that are allowed before the wait is stopped. if set to None (default), no maximum will be used.

property 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.

property 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.

7.26 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*.

7.26.1 Parker GV6 Servo Motor Controller

class pymeasure.instruments.parker.**ParkerGV6**(*port*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Parker Gemini GV6 Servo Motor Controller and provides a high-level interface for interacting with the instrument

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

property angle_error
Returns the angle error in degrees based on the position error, or returns None on error

disable()
Disables the motor from moving

echo(*enable=False*)
Enables (True) or disables (False) the echoing of all commands that are sent to the instrument

enable()
Enables the motor to move

is_moving()
Returns True if the motor is currently moving

kill()
Stops the motor

move()
Initiates the motor to move to the setpoint

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

property position_error
Returns the error in the number of counts that corresponds to the error in the angular position where 1 revolution equals 4000 counts

read()
Overwrites the Instrument.read command to provide the correct functionality

reset()
Resets the motor controller while blocking and (CAUTION) resets the absolute position value of the motor

set_defaults()
Sets up the default values for the motor, which is run upon construction

set_hardware_limits(*positive=True*, *negative=True*)
Enables (True) or disables (False) the hardware limits for the motor

set_software_limits(*positive*, *negative*)
Sets the software limits for motion based on the count unit where 4000 counts is 1 revolution

property status
Returns a list of the motor status in readable format

stop()
Stops the motor during movement

use_absolute_position()
Sets the motor to accept setpoints from an absolute zero position

use_relative_position()
Sets the motor to accept setpoints that are relative to the last position

write(*command*)
Overwrites the Insturment.write command to provide the correct line break syntax

7.27 Pendulum

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

7.27.1 Pendulum CNT91 frequency counter

class pymeasure.instruments.pendulum.cnt91.**CNT91**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents a Pendulum CNT-91 frequency counter.

property batch_size
Maximum number of buffer entries that can be transmitted at once.

buffer_frequency_time_series(*channel*, *n_samples*, *sample_rate*, *trigger_source=None*)
Record a time series to the buffer and read it out after completion.

Parameters

- **channel** – Channel that should be used
- **n_samples** – The number of samples
- **sample_rate** – Sample rate in Hz
- **trigger_source** – Optionally specify a trigger source to start the measurement

configure_frequency_array_measurement(*n_samples*, *channel*)
Configure the counter for an array of measurements.

Parameters

- **n_samples** – The number of samples
- **channel** – Measurment channel (A, B, C, E, INTREF)

property continuous
Controls whether to perform continuous measurements.

property external_arming_start_slope
Set slope for the start arming condition.

property external_start_arming_source
Select arming input or switch off the start arming function. Options are 'A', 'B' and 'E' (rear). 'IMM' turns trigger off.

property format
Reponse format (ASCII or REAL).

property interpolator_autocalibrated
Controls if interpolators should be calibrated automatically.

property measurement_time
Gate time for one measurement in s.

read_buffer(*expected_length=0*)
Read out the entire buffer.

Parameters **expected_length** – The expected length of the buffer. If more data is read, values at the end are removed. Defaults to 0, which means that the entire buffer is returned independent of its length.

Returns Frequency values from the buffer.

7.28 Razorbill

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

7.28.1 Razorbill RP100 custrom power supply for Razorbill Instrums stress & strain cells

class pymeasure.instruments.razorbill.**razorbillRP100**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents Razorbill RP100 strain cell controller

```
scontrol = razorbillRP100("ASRL/dev/ttyACM0::INSTR")

scontrol.output_1 = True      # turns output on
scontrol.slew_rate_1 = 1      # sets slew rate to 1V/s
scontrol.voltage_1 = 10       # sets voltage on output 1 to 10V
```

property contact_current_1
Returns the current in amps present at the front panel output of channel 1

property contact_current_2
Returns the current in amps present at the front panel output of channel 2

property contact_voltage_1
Returns the Voltage in volts present at the front panel output of channel 1

property contact_voltage_2
Returns the Voltage in volts present at the front panel output of channel 2

property instant_voltage_1
Returns the instantaneous output of source one in volts

property instant_voltage_2
Returns the instanteneous output of source two in volts

property output_1
Turns output of channel 1 on or off

property output_2
Turns output of channel 2 on or off

property slew_rate_1
Sets or queries the source slew rate in volts/sec of channel 1

property slew_rate_2
Sets or queries the source slew rate in volts/sec of channel 2

property voltage_1
Sets or queries the output voltage of channel 1

property voltage_2
Sets or queries the output voltage of channel 2

7.29 Rohde & Schwarz

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

7.29.1 R&S SFM TV test transmitter

class pymeasure.instruments.rohdeschwarz.sfm.**SFM**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Rohde&Schwarz SFM TV test transmitter interface for interacting with the instrument.

Note: The current implementation only works with the first system in this unit.

Further source extension for system 2-6 would be required.

The intermodulation subsystem is also not yet implmented.

---

property R75_out
A bool property that controls the use of the 75R output (if installed)

Value	Meaning
False	50R output active (N)
True	75R output active (BNC)

refer also to chapter 3.6.5 of the manual

property TV_country
A string property that controls the country specifics of the video/sound system to be used

Possible values are:

Value	Meaning
BG_G	BG General
DK_G	DK General
I_G	I General
L_G	L General
GERM	Germany
BELG	Belgium
NETH	Netherlands
FIN	Finland
AUST	Australia
BG_T	BG Th
DENM	Denmark
NORW	Norway
SWED	Sweden
GUS	Russia
POL1	Poland
POL2	Poland
HUNG	Hungary
CHEC	Czech Republic
CHINA1	China
CHINA2	China
GRE	Great Britain
SAFR	South Africa
FRAN	France
USA	United States
KOR	Korea
JAP	Japan
CAN	Canada
SAM	South America

Please confirm with the manual about the details for these settings.

property TV_standard

A string property that controls the type of video standard

Possible values are:

Value	Lines	System
BG	625	PAL
DK	625	SECAM
I	625	PAL
K1	625	SECAM
L	625	SECAM
M	525	NTSC
N	625	NTSC

Please confirm with the manual about the details for these settings.

property basic_info

A String property containing infomation about the hardware modules installed in the unit

property beeper_enabled

A bool property that controls the beeper status,

refer also to chapter 3.6.8 of the manual

calibration(*number=1*, *subsystem=None*)
Function to either calibrate the whole modulator, when subsystem parameter is omitted, or calibrate a subsystem of the modulator.

Valid subsystem selections: "NICam, VISion, SOUNd1, SOUNd2, CODer"

channel_down_relative()
Decreases the output frequency to the next low channel/special channel based on the current country settings

property channel_sweep_start
A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property channel_sweep_step
A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property channel_sweep_stop
A float property controlling the start frequency for channel sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property channel_table
A string property controlling which channel table is used

Possible selections are:

Value	Meaning
DEF	Default channel table
USR1	User table No. 1
USR2	User table No. 2
USR3	User table No. 3
USR4	User table No. 4
USR5	User table No. 5

refer also to chapter 3.6.6.1 of the manual

channel_up_relative()
Increases the output frequency to the next higher channel/special channel based on the current country settings

coder_adjust()
Starts the automatic setting of the differential deviation

refer also to chapter 3.6.6.4 of the manual

property coder_id_frequency
A int property that controls the frequency of the identification of the coder

valid range 0 .. 200 Hz

property coder_modulation_degree
A float property that controls the modulation degree of the identification of the coder

valid range: 0 .. 0.9

property coder_pilot_deviation
A int property that controls deviation of the pilot frequency of the coder

valid range: 1 .. 4 kHz

property coder_pilot_frequency
A int property that controls the pilot frequency of the coder

valid range: 40 .. 60 kHz

property cw_frequency
A float property controlling the CW-frequency in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property date
A list property for the date of the RTC in the unit

property event_reg
Content of the event register of the Status Operation Register refer also to chapter 3.6.7 of the manual

property ext_ref_base_unit
A bool property for the external reference for the basic unit

Value	Meaning
False	Internal 10 MHz is used
True	External 10 MHz is used

property ext_ref_extension
A bool property for the external reference for the extension frame

Value	Meaning
False	Internal 10 MHz is used
True	External 10 MHz is used

property ext_vid_connector
A string property controlling which connector is used as the input of the video source

Possible selections are:

Value	Meaning
HIGH	Front connector - Hi-Z
LOW	Front connector - 75R
REAR1	Rear connector 1
REAR2	Rear connector 2
AUTO	Automatic assignment

property external_modulation_frequency
A int property that controls the setting for the external modulator frequency

valid range: 32 .. 46 MHz

property external_modulation_power
A int property that controls the setting for the external modulator output power

valid range: -7..0 dBm

refer also to chapter 3.6.6.5 of the manual

property external_modulation_source
A bool property for the modulation source selection

refer also to chapter 3.6.6.8 of the manual

property frequency
A float property controlling the frequency in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property frequency_mode
A string property controlling which the unit is used in

Possible selections are:

Value	Meaning
CW	Continous wave mode
FIXED	fixed frequency mode
CHSW	Channel sweep
RFSW	Frequency sweep

Note: selecting the sweep mode, will start the sweep imemdiately!

property gpib_address
A int property that controls the GPIB address of the unit

valid range: 0..30

property high_frequency_resolution
A property that controls the frequency resolution,

Possible selections are:

Value	Meaning
False	Low resolution (1000Hz)
True	High resolution (1Hz)

property level
A float property controlling the output level in dBm,

- Minimum -99dBm
- Maximum 10dBm (depending on output mode)

refer also to chapter 3.6.6.2 of the manual

property level_mode
A string property controlling the output attenuator and linearity mode

Possible selections are:

Value	Meaning	max. output level
NORM	Normal mode	+6 dBm
LOWN	low noise mode	+10 dBm
CONT	continous mode	+10 dBm
LOWD	low distortion mode	+0 dBm

Contiuous mode allows up to 14 dB of level setting without use of the mechanical attenuator.

property lower_sideband_enabled
A bool property that controls the use of the lower sideband

refer also to chapter 3.6.6.10 of the manual

property modulation_enabled
A bool property that controls the modulation status

property nicam_IQ_inverted
A bool property that controls if the NICAM IQ signals are inverted or not

Value	Meaning
False	normal (IQ)
True	inverted (QI)

property nicam_additional_bits
A int property that controls the additional data in the NICAM modulator

valid range: 0 .. 2047

property nicam_audio_frequency
A int property that controls the frequency of the internal sound generator

valid range: 0 Hz .. 15 kHz

property nicam_audio_volume
A float property that controls the audio volume in the NICAM modulator in dB

valid range: 0..60 dB

property nicam_bit_error_enabled
A bool property that controls the status of an artifical bit error rate to be applied

property nicam_bit_error_rate
A float property that controls the artifical bit error rate.

valid range: 1.2E-7 .. 2E-3

property nicam_carrier_enabled
A bool property that controls if the NICAM carrier is switched on or off

property nicam_carrier_frequency
A float property that controls the frequency of the NICAM carrier

valid range: 33.05 MHz +/- 0.2 Mhz

property nicam_carrier_level
A float property that controls the value of the NICAM carrier

valid range: -40 .. -13 dB

property nicam_control_bits
A int property that controls the additional data in the NICAM modulator

valid range: 0 .. 3

property nicam_data
A int property that controls the data in the NICAM modulator

valid range: 0 .. 2047

property nicam_intercarrier_frequency
A float property that controls the inter-carrier frequency of the NICAM carrier

valid range: 5 .. 9 MHz

property nicam_mode
A string property that controls the signal type to be sent via NICAM

Possible values are:

Value	Meaning
MON	Mono sound + NICAM data
STER	Stereo sound
DUAL	Dual channel sound
DATA	NICAM data only

refer also to chapter 3.6.6.6 of the manual

property nicam_preemphasis_enabled
A bool property that controls the status of the J17 preemphasis

property nicam_source
A string property that controls the signal source for NICAM

Possible values are:

Value	Meaning
INT	Internal audio generator(s)
EXT	External audio source
CW	Continous wave signal
RAND	Random data stream
TEST	Test signal

property nicam_test_signal
A int property that controls the selection of the test signal applied

Value	Meaning
1	Test signal 1 (91 kHz square wave, I&Q 90deg apart)
2	Test signal 2 (45.5 kHz square wave, I&Q 90deg apart)
3	Test signal 3 (182 kHz sine wave, I&Q in phase)

property normal_channel
A int property controlling the current selected regular/normal channel number valid selections are based on the country settings.

property operation_enable_reg
Content of the enable register of the Status Operation Register

Valid range: 0...32767

property output_voltage
A float property controlling the output level in Volt,

Minimum 2.50891e-6, Maximum 0.707068 (depending on output mode) refer also to chapter 3.6.6.12 of the manual

property questionable_event_reg
Content of the event register of the Status Questionable Operation Register

property questionable_operation_enable_reg
Content of the enable register of the Status Questionable Operation Register

Valid range 0...32767

property questionanble_status_reg
Content of the condition register of the Status Questionable Operation Register

property remote_interfaces
A string property controlling the selection of interfaces for remote control

Possible selections are:

Value	Meaning
OFF	no remote control
GPIB	GPIB only enabled
SER	RS232 only enabled
BOTH	GPIB & RS232 enabled

property rf_out_enabled
A bool property that controls the status of the RF-output

property rf_sweep_center
A float property controlling the center frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property rf_sweep_span
A float property controlling the sweep span in Hz,

- Minimum 1 kHz
- Maximum 1 GHz

property rf_sweep_start
A float property controlling the start frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property rf_sweep_step
A float property controlling the stepwidth for sweep in Hz,

- Minimum 1 kHz
- Maximum 1 GHz

property rf_sweep_stop
A float property controlling the stop frequency for sweep in Hz

- Minimum 5 MHz
- Maximum 1 GHz

property scale_volt
A string property that controls the unit to be used for voltage entries on the unit

Possible values are: AV,FV, PV, NV, UV, MV, V, KV, MAV, GV, TV, PEV, EV, DBAV, DBFV, DBPV, DBNV, DBUV, DBMV, DBV, DBKV, DBMAv, DBGV, DBTV, DBPEv, DBEV

refer also to chapter 3.6.9 of the manual

property serial_baud
A int property that controls the serial communication speed ,

Possible values are: 110,300,600,1200,4800,9600,19200

property serial_bits
A int property that controls the number of bits used in serial communication

Possible values are: 7 or 8

property serial_flowcontrol
A string property that controls the serial handshake type used in serial communication

Possible values are:

Value	Meaning
NONE	no flow-control/handshake
XON	XON/XOFF flow-control
ACK	hardware handshake with RTS&CTS

property serial_parity
A string property that controls the parity type used for serial communication

Possible values are:

Value	Meaning
NONE	no parity
EVEN	even parity
ODD	odd parity
ONE	parity bit fixed to 1
ZERO	parity bit fixed to 0

property serial_stopbits
A int property that controls the number of stop-bits used in serial communication,

Possible values are: 1 or 2

property sound_mode
A string property that controls the type of audio signal

Possible values are:

Value	Meaning
MONO	MOnoaural sound
PIL	pilot-carrier + mono
BTSC	BTSC + mono
STER	Stereo sound
DUAL	Dual channel sound
NIC	NICAM + Mono

property special_channel
A int property controlling the current selected special channel number valid selections are based on the country settings.

property status_info_shown
A bool property that controls if the display shows infomation during remote control

status_preset()
partly resets the SCPI status reporting structures

property status_reg
Content of the condition register of the Status Operation Register

property subsystem_info
A String property containing infomation about the system configuration

property system_number
A int property for the selected systems (if more than 1 available)

- Minimum 1
- Maximum 6

property time
A list property for the time of the RTC in the unit

property vision_average_enabled
A bool property that controls the average mode for the vision system

property vision_balance
A float property that controls the balance of the vision modulator

valid range: -0.5 .. 0.5

property vision_carrier_enabled
A bool property that controls the vision carrier status

refer also to chapter 3.6.6.9 of the manual

property vision_carrier_frequency
A float property that controls the frequency of the vision carrier

valid range: 32 .. 46 MHz

property vision_clamping_average
A float property that controls the operation point of the vision modulator

valid range: -0.5 .. 0.5

property vision_clamping_enabled
A bool property that controls the clamping behavior of the vision modulator

property vision_clamping_mode
A string property that controls the clamping mode of the vision modulator

Possible selections are HARD or SOFT

property vision_precorrection_enabled
A bool property that controls the precorrection behavior of the vision modulator

property vision_residual_carrier_level
A float property that controls the value of the residual carrier

valid range: 0 .. 0.3 (30%)

property vision_sideband_filter_enabled
A bool property that controls the use of the VSBF (vestigal sideband filter) in the vision modulator

property vision_videosignal_enabled
A bool property that controls if the video signal is switched on or off

class pymeasure.instruments.rohdeschwarz.sfm.**Sound_Channel**(*instrument*, *number*)
Bases: object

Class object for the two sound channels

refere also to chapter 3.6.6.7 of the user manual

property carrier_enabled
A bool property that controls if the audio carrier is switched on or off

property carrier_frequency
A float property that controls the frequency of the sound carrier

valid range: 32 .. 46 MHz

property carrier_level
A float property that controls the level of the audio carrier in dB relative to the vision carrier (0dB)

valid range: -34 .. -6 dB

property deviation
A int property that controls deviation of the selected audio signal

valid range: 0 .. 110 kHz

property frequency
A int property that controls the frequency of the internal sound generator

valid range: 300 Hz .. 15 kHz

property modulation_degree
A float property that controls the modulation depth for the audio signal (Note: only for the use of AM in Standard L)

valid range: 0 .. 1 (100%)

property modulation_enabled
A bool property that controls the audio modulation status

Value	Meaning
False	modulation disabled
True	modulation enabled

property preemphasis_enabled
A bool property that controls if the preemphasis for the audio is switched on or off

property preemphasis_time
A int property that controls if the mode of the preemphasis for the audio signal

Value	Meaning
50	50 us preemphasis
75	75 us preemphasis

property use_external_source
A bool property for the audio source selection

Value	Meaning
False	Internal audio generator(s)
True	External signal source

values(*command*, ***kwargs*)
Reads a set of values from the instrument through the adapter, passing on any keyword arguments.

7.29.2 R&S FSL spectrum analyzer

Connecting to the instrument via network

Once connected to the network, the instrument's IP address can be found by clicking the "Setup" button and navigating to "General Settings" -> "Network Address".

It can then be connected like this:

```
from pymeasure.instruments.rohdeschwarz import FSL
fsl = FSL("TCPIP::192.168.1.123::INSTR")
```

Getting and setting parameters

Most parameters are implemented as properties, which means they can be read and written (getting and setting) in a consistent and simple way. If numerical values are provided, base units are used (s, Hz, dB, ...). Alternatively, the values can also be provided with a unit, e.g. `"1.5 GHz"` or `"1.5GHz"`. Return values are always numerical.

```
# Getting the current center frequency
fsl.freq_center

9000000000.0
```

```
# Changing it to 10 MHz by providing the numerical value
fsl.freq_center = 10e6
```

```
# Verifying:
fsl.freq_center

10000000.0
```

```
# Changing it to 9 GHz by providing a string and verifying the result
fsl.freq_center = '9GHz'
fsl.freq_center

9000000000.0
```

```
# Setting the span to maximum
fsl.freq_span = '7 GHz'
```

Reading a trace

We will read the current trace

```
x, y = fsl.read_trace()
```

Markers

Markers are implemented as their own class. You can create them like this:

```
m1 = fsl.create_marker()
```

Set peak exursion:

```
m1.peak_excursion = 3
```

Set marker to a specific position:

```
m1.x = 10e9
```

Find the next peak to the left and get the level:

```
m1.to_next_peak('left')
m1.y

-34.9349060059
```

Delta markers

Delta markers can be created by setting the appropriate keyword.

```
d2 = fsl.create_marker(is_delta_marker=True)
d2.name

'DELT2'
```

Example program

Here is an example of a simple script for recording the peak of a signal.

```
m1 = fsl.create_marker() # create marker 1

# Set standard settings, set to full span
fsl.continuous_sweep = False
fsl.freq_span = '18 GHz'
fsl.res_bandwidth = "AUTO"
fsl.video_bandwidth = "AUTO"
fsl.sweep_time = "AUTO"

# Perform a sweep on full span, set the marker to the peak and some to that marker
fsl.single_sweep()
m1.to_peak()
m1.zoom('20 MHz')

# take data from the zoomed-in region
fsl.single_sweep()
x, y = fsl.read_trace()
```

class pymeasure.instruments.rohdeschwarz.fsl.**FSL**(*resourceName*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents a Rohde&Schwarz FSL spectrum analyzer.

All physical values that can be set can either be as a string of a value and a unit (e.g. "1.2 GHz") or as a float value in the base units (Hz, dBm, etc.).

property attenuation
Attenuation in dB.

continue_single_sweep()
Continue with single sweep with synchronization.

property continuous_sweep
Continuous (True) or single sweep (False)

create_marker(*num=1*, *is_delta_marker=False*)
Create a marker.

Parameters

- **num** – The marker number (1-4)
- **is_delta_marker** – True if the marker is a delta marker, default is False.

Returns The marker object.

property freq_center
Center frequency in Hz.

property freq_span
Frequency span in Hz.

property freq_start
Start frequency in Hz.

property freq_stop
Stop frequency in Hz.

read_trace(*n_trace=1*)
Read trace data.

Parameters **n_trace** – The trace number (1-6). Default is 1.

Returns 2d numpy array of the trace data, [[frequency], [amplitude]].

property res_bandwidth
Resolution bandwidth in Hz. Can be set to 'AUTO'

single_sweep()
Perform a single sweep with synchronization.

property sweep_time
Sweep time in s. Can be set to 'AUTO'.

property trace_mode
Trace mode ('WRIT', 'MAXH', 'MINH', 'AVER' or 'VIEW')

property video_bandwidth
Video bandwidth in Hz. Can be set to 'AUTO'

7.30 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*.

7.30.1 DSP 7265 Lock-in Amplifier

class pymeasure.instruments.signalrecovery.**DSP7265**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

This is the class for the DSP 7265 lockin amplifier

property adc1
Reads the input value of ADC1 in Volts

property adc2
Reads the input value of ADC2 in Volts

buffer_to_float(*buffer_data*, *sensitivity=None*, *sensitivity2=None*, *raise_error=True*)
Method that converts the fixed-point buffer data to floating point data. The provided data is converted as much as possible, but there are some requirements to the data if all provided columns are to be converted; if a key in the provided data cannot be converted it will be omitted in the returned data or an exception will be raised, depending on the value of raise_error.

The requirements for converting the data are as follows:

- Converting X, Y, magnitude and noise requires sensitivity data, which can either be part of the provided data or can be provided via the sensitivity argument
- The same holds for X2, Y2, magnitude2 and noise2 with sensitivity2.
- Converting the frequency requires both 'frequency part 1' and 'frequency part 2'.

Parameters

- **buffer_data** (*dict*) – The data to be converted. Must be in the format as returned by the *get_buffer* method: a dict of numpy arrays.

- **sensitivity** – If provided, the sensitivity used to convert X, Y, magnitude and noise. Can be provided as a float or as an array that matches the length elements in the buffer_data. If both a sensitivity is provided and present in the buffer_data, the provided value is used for the conversion, but the sensitivity in the buffer_data is stored in the returned dict.
- **sensitivity2** – Same as the first sensitivity argument, but for X2, Y2, magnitude2 and noise2.
- **raise_error** (*bool*) – Boolean that determines whether an exception is raised in case not all keys provided in buffer_data can be converted. If False, the columns that cannot be converted are omitted in the returned dict.

property curve_buffer_bits
An integer property that controls which data outputs are stored in the curve buffer. Valid values are values between 1 and 65,535 (or 2,097,151 in dual reference mode).

property curve_buffer_interval
An integer property that controls Sets the time interval between successive points being acquired in the curve buffer. The time interval is specified in ms with a resolution of 5 ms; input values are rounded up to a multiple of 5. Valid values are values between 0 and 1,000,000,000 (corresponding to 12 days). The interval may be set to 0, which sets the rate of data storage to the curve buffer to 1.25 ms/point (800 Hz). However this only allows storage of the X and Y channel outputs. There is no need to issue a CBD 3 command to set this up since it happens automatically when acquisition starts.

property curve_buffer_length
An integer property that controls the length of the curve buffer. Valid values are values between 1 and 32,768, but the actual maximum amount of points is determined by the amount of curves that are stored, as set via the curve_buffer_bits property (32,768 / n)

property curve_buffer_status
A property that represents the status of the curve buffer acquisition with four values: the first value represents the status with 5 possibilities (0: no activity, 1: acquisition via TD command running, 2: acquisition bya TDC command running, 5: acquisition via TD command halted, 6: acquisition bia TDC command halted); the second value is the number of sweeps that is acquired; the third value is the decimal representation of the status byte (the same response as the ST command; the fourth value is the number of points acquired in the curve buffer.

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

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

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

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

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

get_buffer(*quantity=None*, *convert_to_float=True*, *wait_for_buffer=True*)
Method that retrieves the buffer after it has been filled. The data retrieved from the lock-in is in a fixed-point format, which requires translation before it can be interpreted as meaningful data. When *convert_to_float* is True the conversion is performed (if possible) before returning the data.

Parameters

- **quantity** (*str*) – If provided, names the quantity that is to be retrieved from the curve buffer; can be any of: 'x', 'y', 'magnitude', 'phase', 'sensitivity', 'adc1', 'adc2', 'adc3', 'dac1', 'dac2', 'noise', 'ratio', 'log ratio', 'event', 'frequency part 1' and 'frequency part 2'; for both dual modes, additional options are: 'x2', 'y2', 'magnitude2', 'phase2', 'sensitivity2'. If no quantity is provided, all available data is retrieved.
- **convert_to_float** (*bool*) – Bool that determines whether to convert the fixed-point buffer-data to meaningful floating point values via the *buffer_to_float* method. If True, this method tries to convert all the available data to meaningful values; if this is not possible, an exception will be raised. If False, this conversion is not performed and the raw buffer-data is returned.
- **wait_for_buffer** (*bool*) – Bool that determines whether to wait for the data acquisition to finished if this method is called before the acquisition is finished. If True, the method waits until the buffer is filled before continuing; if False, the method raises an exception if the acquisition is not finished when the method is called.

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

property id
Reads the instrument identification

property imode
Property that controls the voltage/current mode. can be 'voltage mode', 'current mode', or 'low noise current mode'

init_curve_buffer()
Initializes the curve storage memory and status variables. All record of previously taken curves is removed.

property log_ratio
Reads the log ratio output, defined as log(X/ADC1)

property mag
Reads the magnitude in Volts

property phase
Reads the phase in degrees

property ratio
Reads the ratio output, defined as X/ADC1

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

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

property sensitivity
A floating point property that controls the sensitivity range in Volts (for voltage mode) or Amps (for current modes). When in Volts it takes discrete values from 2 nV to 1 V. When in Amps it takes discrete values from 2 fA to 1 μA (for normal current mode) or up to 10 nA (for low noise current mode). This property can be set.

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

set_buffer(*points*, *quantities=None*, *interval=0.01*)
Method that prepares the curve buffer for a measurement.

Parameters

- **points** (*int*) – Number of points to be recorded in the curve buffer
- **quantities** (*list*) – List containing the quantities (strings) that are to be recorded in the curve buffer, can be any of: 'x', 'y', 'magnitude', 'phase', 'sensitivity', 'adc1', 'adc2', 'adc3', 'dac1', 'dac2', 'noise', 'ratio', 'log ratio', 'event', 'frequency' (or 'frequency part 1' and 'frequency part 2'); for both dual modes, additional options are: 'x2', 'y2', 'magnitude2', 'phase2', 'sensitivity2'. Default is 'x' and 'y'.
- **interval** (*float*) – The interval between two subsequent points stored in the curve buffer in s. Default is 10 ms.

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

property slope
A integer property that controls the filter slope in dB/octave, which can take the values 6, 12, 18, or 24 dB/octave. This property can be set.

start_buffer()
Initiates data acquisition. Acquisition starts at the current position in the curve buffer and continues at the rate set by the STR command until the buffer is full.

property time_constant
A floating point property that controls the time constant in seconds, which takes values from 10 microseconds to 50,000 seconds. This property can be set.

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

wait_for_buffer(*timeout=None*, *delay=0.1*)
Method that waits until the curve buffer is filled

property x
Reads the X value in Volts

property xy
Reads both the X and Y values in Volts

property y
Reads the Y value in Volts

7.31 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*.

7.31.1 SR510 Lock-in Amplifier

class pymeasure.instruments.srs.**SR510**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

property frequency
A float property representing the SR510 input reference frequency

property output
A float property that represents the SR510 output voltage in Volts.

property phase
A float property that represents the SR510 reference to input phase offset in degrees. Queries return values between -180 and 180 degrees. This property can be set with a range of values between -999 to 999 degrees. Set values are mapped internal in the lockin to -180 and 180 degrees.

property sensitivity
A float property that represents the SR510 sensitivity value. This property can be set.

property status
A string property representing the bits set within the SR510 status byte

property time_constant
A float property that represents the SR510 PRE filter time constant. This property can be set.

7.31.2 SR570 Lock-in Amplifier

class pymeasure.instruments.srs.**SR570**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

property bias_enabled
Boolean that turns the bias on or off. Allowed values are: True (bias on) and False (bias off)

property bias_level
A floating point value in V that sets the bias voltage level of the amplifier, in the [-5V,+5V] limits. The values are up to 1 mV precision level.

blank_front()
“Blanks the frontend output of the device

clear_overload()
“Reset the filter capacitors to clear an overload condition

disable_bias()
Turns the bias voltage off

disable_offset_current()
“Disables the offset current

enable_bias()
Turns the bias voltage on

enable_offset_current()
“Enables the offset current

property filter_type
A string that sets the filter type. Allowed values are: [‘6dB Highpass’, ‘12dB Highpass’, ‘6dB Bandpass’, ‘6dB Lowpass’, ‘12dB Lowpass’, ‘none’]

property front_blanked
Boolean that blanks(True) or un-blanks (False) the front panel

property gain_mode
A string that sets the gain mode. Allowed values are: ['Low Noise', 'High Bandwidth', 'Low Drift']

property high_freq
A floating point value that sets the highpass frequency of the amplifier, which takes a discrete value in a 1-3 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 0.03 Hz to 1 MHz.

property invert_signal_sign
An boolean sets the signal invert sense. Allowed values are: True (inverted) and False (not inverted).

property low_freq
A floating point value that sets the lowpass frequency of the amplifier, which takes a discrete value in a 1-3 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 0.03 Hz to 1 MHz.

property offset_current
A floating point value in A that sets the absolute value of the offset current of the amplifier, in the [1pA,5mA] limits. The offset current takes discrete values in a 1-2-5 sequence. Values are truncated to the closest allowed value if not exact.

property offset_current_enabled
Boolean that turns the offset current on or off. Allowed values are: True (current on) and False (current off).

property offset_current_sign
An string that sets the offset current sign. Allowed values are: 'positive' and 'negative'.

property sensitivity
A floating point value that sets the sensitivity of the amplifier, which takes discrete values in a 1-2-5 sequence. Values are truncated to the closest allowed value if not exact. Allowed values range from 1 pA/V to 1 mA/V.

property signal_inverted
Boolean that inverts the signal if True

unblank_front()
Un-blanks the frontend output of the device

7.31.3 SR830 Lock-in Amplifier

class pymeasure.instruments.srs.**SR830**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

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

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

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

property adc4
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

auto_offset(*channel*)
Offsets the channel (X, Y, or R) to zero

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

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

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

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

property aux_out_1
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_2
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_3
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_4
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property channel1
A string property that represents the type of Channel 1, taking the values X, R, X Noise, Aux In 1, or Aux In 2. This property can be set.

property channel2
A string property that represents the type of Channel 2, taking the values Y, Theta, Y Noise, Aux In 3, or Aux In 4. This property can be set.

property dac1
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac2
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac3
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac4
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property err_status
Reads the value of the lockin error (ERR) status byte. Returns an IntFlag type with positions within the string corresponding to different error flags: bit 0: unused bit 1: backup error bit 2: RAM error bit 3: unused bit 4: ROM error bit 5: GPIB error bit 6: DSP error bit 7: Math error

property filter_slope
An integer property that controls the filter slope, which can take on the values 6, 12, 18, and 24 dB/octave. Values are truncated to the next highest level if they are not exact.

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

get_buffer(*channel=1*, *start=0*, *end=None*)
Aquires the 32 bit floating point data through binary transfer

get_scaling(*channel*)
Returns the offset precent and the exapnsion term that are used to scale the channel in question

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

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

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

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

property input_notch_config
An string property that controls the input line notch filter status. Allowed values are: ['None', 'Line', '2 x Line', 'Both']

is_out_of_range()
Returns True if the magnitude is out of range

property lia_status
Reads the value of the lockin amplifier (LIA) status byte. Returns a binary string with positions within the string corresponding to different status flags: bit 0: Input/Amplifier overload bit 1: Time constant filter overload bit 2: Output overload bit 3: Reference unlock bit 4: Detection frequency range switched bit 5: Time constant changed indirectly bit 6: Data storage triggered bit 7: unused

property magnitude
Reads the magnitude in Volts.

output_conversion(*channel*)
Returns a function that can be used to determine the signal from the channel output (X, Y, or R)

property phase
A floating point property that represents the lock-in phase in degrees. This property can be set.

quick_range()
While the magnitude is out of range, increase the sensitivity by one setting

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

property sample_frequency
Gets the sample frequency in Hz

property sensitivity
A floating point property that controls the sensitivity in Volts, which can take discrete values from 2 nV to 1 V. Values are truncated to the next highest level if they are not exact.

set_scaling(*channel*, *precent*, *expand=0*)
Sets the offset of a channel (X=1, Y=2, R=3) to a certain precent (-105% to 105%) of the signal, with an optional expansion term (0, 10=1, 100=2)

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

snap(*val1='X'*, *val2='Y'*, **vals*)
Method that records and retrieves 2 to 6 parameters at a single instant. The parameters can be one of: X, Y, R, Theta, Aux In 1, Aux In 2, Aux In 3, Aux In 4, Frequency, CH1, CH2. Default is "X" and "Y".

Parameters

- **val1** – first parameter to retrieve
- **val2** – second parameter to retrieve
- **vals** – other parameters to retrieve (optional)

property theta
Reads the theta value in degrees.

property time_constant
A floating point property that controls the time constant in seconds, which can take discrete values from 10 microseconds to 30,000 seconds. Values are truncated to the next highest level if they are not exact.

wait_for_buffer(*count*, *has_aborted=<function SR830.<lambda>>*, *timeout=60*, *timestep=0.01*)
Wait for the buffer to fill a certain count

property x
Reads the X value in Volts.

property xy
Reads the X and Y values in Volts.

property y
Reads the Y value in Volts.

7.31.4 SR860 Lock-in Amplifier

class pymeasure.instruments.srs.**SR860**(*resourceName*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

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

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

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

property adc4
Reads the Aux input 4 value in Volts with 1/3 mV resolution.

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

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

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

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

property aux_out_1
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_2
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_3
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property aux_out_4
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac1
A floating point property that controls the output of Aux output 1 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac2
A floating point property that controls the output of Aux output 2 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac3
A floating point property that controls the output of Aux output 3 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dac4
A floating point property that controls the output of Aux output 4 in Volts, taking values between -10.5 V and +10.5 V. This property can be set.

property dcmode
A string property that represents the sine out dc mode. This property can be set. Allowed values are:[‘COM’, ‘DIF’, ‘common’, ‘difference’]

property detectedfrequency
Returns the actual detected frequency in HZ.

property extfreqency
Returns the external frequency in Hz.

property filer_synchronous
A string property that represents the synchronous filter. This property can be set. Allowed values are:[‘Off’, ‘On’]

property filter_advanced
A string property that represents the advanced filter. This property can be set. Allowed values are:[‘Off’, ‘On’]

property filter_slope
A integer property that sets the filter slope to 6 dB/oct(i=0), 12 DB/oct(i=1), 18 dB/oct(i=2), 24 dB/oct(i=3).

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

property frequencypreset1
A floating point property that represents the preset frequency for the F1 preset button. This property can be set.

property frequencypreset2
A floating point property that represents the preset frequency for the F2 preset button. This property can be set.

property frequencypreset3
A floating point property that represents the preset frequency for the F3 preset button. This property can be set.

property frequencypreset4
A floating point property that represents the preset frequency for the F4 preset button. This property can be set.

property front_panel
Turns the front panel blanking on(i=0) or off(i=1).

property get_noise_bandwidth
Returns the equivalent noise bandwidth, in hertz.

property get_signal_strength_indicator
Returns the signal strength indicator.

property gettimebase
Returns the current 10 MHz timebase source.

property harmonic
An integer property that controls the harmonic that is measured. Allowed values are 1 to 99. Can be set.

property harmonicdual
An integer property that controls the harmonic in dual reference mode that is measured. Allowed values are 1 to 99. Can be set.

property horizontal_time_div
A integer property that sets the horizontal time/div according to the following table:[‘0=0.5s’, ‘1=1s’, ‘2=2s’, ‘3=5s’, ‘4=10s’, ‘5=30s’, ‘6=1min’, ‘7=2min’, ‘8=5min’, ‘9=10min’, ‘10=30min’, ‘11=1hour’, ‘12=2hour’, ‘13=6hour’, ‘14=12hour’, ‘15=1day’, ‘16=2days’]

property input_coupling
A string property that represents the input coupling. This property can be set. Allowed values are:[‘AC’, ‘DC’]

property input_current_gain
A string property that represents the current input gain. This property can be set. Allowed values are:[‘1MEG’, ‘100MEG’]

property input_range
A string property that represents the input range. This property can be set. Allowed values are:[‘1V’, ‘300M’, ‘100M’, ‘30M’, ‘10M’]

property input_shields
A string property that represents the input shield grounding. This property can be set. Allowed values are:[‘Float’, ‘Ground’]

property input_signal
A string property that represents the signal input. This property can be set. Allowed values are:[‘VOLT’, ‘CURR’, ‘voltage’, ‘current’]

property input_voltage_mode
A string property that represents the voltage input mode. This property can be set. Allowed values are:['A', 'A-B']

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

property magnitude
Reads the magnitude in Volts.

property parameter_DAT1
A integer property that assigns a parameter to data channel 1(green). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

property parameter_DAT2
A integer property that assigns a parameter to data channel 2(blue). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

property parameter_DAT3
A integer property that assigns a parameter to data channel 3(yellow). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

property parameter_DAT4
A integer property that assigns a parameter to data channel 3(orange). This parameters can be set. Allowed values are:['i=', '0=Xoutput', '1=Youtput', '2=Routput', 'Thetaoutput', '4=Aux IN1', '5=Aux IN2', '6=Aux IN3', '7=Aux IN4', '8=Xnoise', '9=Ynoise', '10=AUXOut1', '11=AuxOut2', '12=Phase', '13=Sine Out amplitude', '14=DCLevel', '15I=nt.referenceFreq', '16=Ext.referenceFreq']

property phase
A floating point property that represents the lock-in phase in degrees. This property can be set.

property reference_externalinput
A string property that represents the external reference input. This property can be set. Allowed values are:['50OHMS', '1MEG']

property reference_source
A string property that represents the reference source. This property can be set. Allowed values are:['INT', 'EXT', 'DUAL', 'CHOP']

property reference_triggermode
A string property that represents the external reference trigger mode. This property can be set. Allowed values are:['SIN', 'POS', 'NEG', 'POSTTL', 'NEGTTL']

property screen_layout
A integer property that Sets the screen layout to trend(i=0), full strip chart history(i=1), half strip chart history(i=2), full FFT(i=3), half FFT(i=4) or big numerical(i=5).

screenshot()
Take screenshot on device The DCAP command saves a screenshot to a USB memory stick. This command is the same as pressing the [Screen Shot] key. A USB memory stick must be present in the front panel USB port.

property sensitvity
A floating point property that controls the sensitivity in Volts, which can take discrete values from 2 nV

to 1 V. Values are truncated to the next highest level if they are not exact.

property sine_amplitudepreset1
A floating point property that represents the preset sine out amplitude, for the A1 preset button. This property can be set.

property sine_amplitudepreset2
A floating point property that represents the preset sine out amplitude, for the A2 preset button. This property can be set.

property sine_amplitudepreset3
A floating point property that represents the preset sine out amplitude, for the A3 preset button. This property can be set.

property sine_amplitudepreset4
A floating point property that represents the preset sine out amplitude, for the A3 preset button. This property can be set.

property sine_dclevelpreset1
A floating point property that represents the preset sine out dc level for the L1 button. This property can be set.

property sine_dclevelpreset2
A floating point property that represents the preset sine out dc level for the L2 button. This property can be set.

property sine_dclevelpreset3
A floating point property that represents the preset sine out dc level for the L3 button. This property can be set.

property sine_dclevelpreset4
A floating point property that represents the preset sine out dc level for the L4 button. This property can be set.

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

snap(*val1='X'*, *val2='Y'*, *val3=None*)
retrieve 2 or 3 parameters at once parameters can be chosen by index, or enumeration as follows:

j enumeration parameter j enumeration parameter

0 X X output 9 YNOise Ynoise 1 Y Youtput 10 OUT1 Aux Out1 2 R R output 11 OUT2 Aux Out2 3 THeta output 12 PHAse Reference Phase 4 IN1 Aux In1 13 SAMp Sine Out Amplitude 5 IN2 Aux In2 14 LEVel DC Level 6 IN3 Aux In3 15 FInt Int. Ref. Frequency 7 IN4 Aux In4 16 FExt Ext. Ref. Frequency 8 XNOise Xnoise

Parameters

- **val1** – parameter enumeration/index
- **val2** – parameter enumeration/index
- **val3** – parameter enumeration/index (optional)

Defaults: val1 = “X” val2 = “Y” val3 = None

property strip_chart_dat1
A integer property that turns the strip chart graph of data channel 1 off(i=0) or on(i=1).

property strip_chart_dat2
A integer property that turns the strip chart graph of data channel 2 off(i=0) or on(i=1).

property strip_chart_dat3
A integer property that turns the strip chart graph of data channel 1 off(i=0) or on(i=1).

property strip_chart_dat4
A integer property that turns the strip chart graph of data channel 4 off(i=0) or on(i=1).

property theta
Reads the theta value in degrees.

property time_constant
A floating point property that controls the time constant in seconds, which can take discrete values from 10 microseconds to 30,000 seconds. Values are truncated to the next highest level if they are not exact.

property timebase
Sets the external 10 MHZ timebase to auto(i=0) or internal(i=1).

property x
Reads the X value in Volts

property y
Reads the Y value in Volts

7.32 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*.

7.32.1 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

7.32.2 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

7.33 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*.

7.33.1 Thorlabs PM100USB Powermeter

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

Bases: *pymeasure.instruments.instrument.Instrument*

Represents Thorlabs PM100USB powermeter.

property energy
Energy in J.

property power
Power in W.

property wavelength
Wavelength in nm.

property wavelength_max
Maximum wavelength, in nm

property wavelength_min
Minimum wavelength, in nm

7.33.2 Thorlabs Pro 8000 modular laser driver

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

Bases: *pymeasure.instruments.instrument.Instrument*

Represents Thorlabs Pro 8000 modular laser driver

property LDCCurrent
Laser current.

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

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

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

property TEDSetTemperature
Set TEC temperature

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

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

7.34 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*.

7.34.1 Yokogawa 7651 Programmable Supply

class pymeasure.instruments.yokogawa.**Yokogawa7651**(*adapter*, ***kwargs*)

Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Yokogawa 7651 Programmable DC Source and provides a high-level for interacting with the instrument.

```
yoko = Yokogawa7651("GPIB::1")

yoko.apply_current()                # Sets up to source current
yoko.source_current_range = 10e-3   # Sets the current range to 10 mA
yoko.compliance_voltage = 10        # Sets the compliance voltage to 10 V
yoko.source_current = 0             # Sets the source current to 0 mA

yoko.enable_source()                # Enables the current output
yoko.ramp_to_current(5e-3)          # Ramps the current to 5 mA

yoko.shutdown()                     # Ramps the current to 0 mA and disables output
```

apply_current(*max_current=0.001*, *compliance_voltage=1*)

Configures the instrument to apply a source current, which can take optional parameters that defer to the *source_current_range* and *compliance_voltage* properties.

apply_voltage(*max_voltage=1*, *compliance_current=0.01*)

Configures the instrument to apply a source voltage, which can take optional parameters that defer to the *source_voltage_range* and *compliance_current* properties.

property compliance_current

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

property compliance_voltage

A floating point property that sets the compliance voltage in Volts, which can take values between 1 and 30 V.

disable_source()

Disables the source of current or voltage depending on the configuration of the instrument.

enable_source()

Enables the source of current or voltage depending on the configuration of the instrument.

property id

Returns the identification of the instrument

ramp_to_current(*current*, *steps=25*, *duration=0.5*)

Ramps the current to a value in Amps by traversing a linear spacing of current steps over a duration, defined in seconds.

Parameters

- **steps** – A number of linear steps to traverse

- **duration** – A time in seconds over which to ramp

ramp_to_voltage(*voltage*, *steps=25*, *duration=0.5*)
Ramps the voltage to a value in Volts by traversing a linear spacing of voltage steps over a duration, defined in seconds.

Parameters

- **steps** – A number of linear steps to traverse
- **duration** – A time in seconds over which to ramp

shutdown()
Shuts down the instrument, and ramps the current or voltage to zero before disabling the source.

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

property source_current_range
A floating point property that sets the current voltage range in Amps, which can take values: 1 mA, 10 mA, and 100 mA. Currents are truncted to an appropriate value if needed.

property source_enabled
Reads a boolean value that is True if the source is enabled, determined by checking if the 5th bit of the OC flag is a binary 1.

property source_mode
A string property that controls the source mode, which can take the values 'current' or 'voltage'. The convenience methods *apply_current()* and *apply_voltage()* can also be used.

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

property source_voltage_range
A floating point property that sets the source voltage range in Volts, which can take values: 10 mV, 100 mV, 1 V, 10 V, and 30 V. Voltages are truncted to an appropriate value if needed.

7.34.2 Yokogawa GS200 Source

class pymeasure.instruments.yokogawa.**YokogawaGS200**(*adapter*, ***kwargs*)
Bases: *pymeasure.instruments.instrument.Instrument*

Represents the Yokogawa GS200 source and provides a high-level interface for interacting with the instrument.

property current_limit
Floating point number that controls the current limit. "Limit" refers to maximum value of the electrical value that is conjugate to the mode (current is conjugate to voltage, and vice versa). Thus, current limit is only applicable when in 'voltage' mode

property source_enabled
A boolean property that controls whether the source is enabled, takes values True or False.

property source_level
Floating point number that controls the output level, either a voltage or a current, depending on the source mode.

property source_mode
String property that controls the source mode. Can be either 'current' or 'voltage'.

property source_range
Floating point number that controls the range (either in voltage or current) of the output. "Range" refers to the maximum source level.

trigger_ramp_to_level(*level*, *ramp_time*)
Ramp the output level from its current value to "level" in time "ramp_time". This method will NOT wait until the ramp is finished (thus, it will not block further code evaluation).

Parameters

- **level** (*float*) – final output level
- **ramp_time** (*float*) – time in seconds to ramp

Returns None

property voltage_limit
Floating point number that controls the voltage limit. "Limit" refers to maximum value of the electrical value that is conjugate to the mode (current is conjugate to voltage, and vice versa). Thus, voltage limit is only applicable when in 'current' mode

CHAPTER

EIGHT

CONTRIBUTING

Contributions to the instrument repository and the main code base are highly encouraged. This section outlines the basic work-flow for new contributors.

8.1 Using the development version

New features are added to the development version of PyMeasure, hosted on GitHub. We use Git version control to track and manage changes to the source code. On Windows, we recommend using GitHub Desktop. Make sure you have an appropriate version of Git (or GitHub Desktop) installed and that you have a GitHub account.

In order to add your feature, you need to first fork PyMeasure. This will create a copy of the repository under your GitHub account.

The instructions below assume that you have set up Anaconda, as described in the *Quick Start guide* and describe the terminal commands necessary. If you are using GitHub Desktop, take a look through their documentation to understand the corresponding steps.

Clone your fork of PyMeasure `your-github-username/pymeasure`. In the following terminal commands replace your desired path and GitHub username.

```
cd /path/for/code
git clone https://github.com/your-github-username/pymeasure.git
```

If you had already installed PyMeasure using `pip`, make sure to uninstall it before continuing.

```
pip uninstall pymeasure
```

Install PyMeasure in the editable mode.

```
cd /path/for/code/pymeasure
pip install -e .
```

This will allow you to edit the files of PyMeasure and see the changes reflected. Make sure to reset your notebook kernel or Python console when doing so. Now you have your own copy of the development version of PyMeasure installed!

8.2 Working on a new feature

We use branches in Git to allow multiple features to be worked on simultaneously, without causing conflicts. The master branch contains the stable development version. Instead of working on the master branch, you will create your own branch off the master and merge it back into the master when you are finished.

Create a new branch for your feature before editing the code. For example, if you want to add the new instrument "Extreme 5000" you will make a new branch "dev/extreme-5000".

```
git branch dev/extreme-5000
```

You can also make a new branch on GitHub. If you do so, you will have to fetch these changes before the branch will show up on your local computer.

```
git fetch
```

Once you have created the branch, change your current branch to match the new one.

```
git checkout dev/extreme-5000
```

Now you are ready to write your new feature and make changes to the code. To ensure consistency, please follow the *coding standards for PyMeasure*. Use `git status` to check on the files that have been changed. As you go, commit your changes and push them to your fork.

```
git add file-that-changed.py
git commit -m "A short description about what changed"
git push
```

8.3 Making a pull-request

While you are working, its helpful to start a pull-request (PR) on the `master` branch of `pymeasure/pymeasure`. This will allow you to discuss your feature with other contributors. We encourage you to start this pull-request after your first commit.

Start a pull-request on the PyMeasure GitHub page.

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

NINE

REPORTING AN ERROR

Please report all errors to the Issues section of the PyMeasure GitHub repository. Use the search function to determine if there is an existing or resolved issued before posting.

CHAPTER

TEN

ADDING INSTRUMENTS

You can make a significant contribution to PyMeasure by adding a new instrument to the `pymeasure.instruments` package. Even adding an instrument with a few features can help get the ball rolling, since its likely that others are interested in the same instrument.

Before getting started, become familiar with the *contributing work-flow* for PyMeasure, which steps through the process of adding a new feature (like an instrument) to the development version of the source code. This section will describe how to lay out your instrument code.

10.1 File structure

Your new instrument should be placed in the directory corresponding to the manufacturer of the instrument. For example, if you are going to add an "Extreme 5000" instrument you should add the following files assuming "Extreme" is the manufacturer. Use lowercase for all filenames to distinguish packages from CamelCase Python classes.

```
pymeasure/pymeasure/instruments/extreme/
    |--> __init__.py
    |--> extreme5000.py
```

10.1.1 Updating the init file

The `__init__.py` file in the manufacturer directory should import all of the instruments that correspond to the manufacturer, to allow the files to be easily imported. For a new manufacturer, the manufacturer should also be added to `pymeasure/pymeasure/instruments/__init__.py`.

10.1.2 Adding documentation

Documentation for each instrument is required, and helps others understand the features you have implemented. Add a new reStructuredText file to the documentation.

```
pymeasure/docs/api/instruments/extreme/
    |--> index.rst
    |--> extreme5000.rst
```

Copy an existing instrument documentation file, which will automatically generate the documentation for the instrument. The `index.rst` file should link to the `extreme5000` file. For a new manufacturer, the manufacturer should be also linked in `pymeasure/docs/api/instruments/index.rst`.

10.2 Instrument file

All standard instruments should be child class of *Instrument*. This provides the basic functionality for working with *Adapters*, which perform the actual communication.

The most basic instrument, for our "Extreme 5000" example starts like this:

```
#
# This file is part of the PyMeasure package.
#
# Copyright (c) 2013-2021 PyMeasure Developers
#
# Permission is hereby granted, free of charge, to any person obtaining a copy
# of this software and associated documentation files (the "Software"), to deal
# in the Software without restriction, including without limitation the rights
# to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
# copies of the Software, and to permit persons to whom the Software is
# furnished to do so, subject to the following conditions:
#
# The above copyright notice and this permission notice shall be included in
# all copies or substantial portions of the Software.
#
# THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
# IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
# FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
# AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
# LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
# OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
# THE SOFTWARE.
#

# from pymeasure.instruments import Instrument
```

This is a minimal instrument definition:

```
class Extreme5000(Instrument):
    """ Represents the imaginary Extreme 5000 instrument.
    """

    def __init__(self, resourceName, **kwargs):
        super().__init__(
            resourceName,
            "Extreme 5000",
            **kwargs
        )
```

Make sure to include the PyMeasure license to each file, and add yourself as an author to the `AUTHORS.txt` file.

In principle you are free to write any functions that are necessary for interacting with the instrument. When doing so, make sure to use the `self.ask(command)`, `self.write(command)`, and `self.read()` methods to issue command instead of calling the adapter directly.

In practice, we have developed a number of convenience functions for making instruments easy to write and maintain. The following sections detail these conveniences and are highly encouraged.

10.3 Writing properties

In PyMeasure, Python properties are the preferred method for dealing with variables that are read or set. PyMeasure comes with two convenience functions for making properties for classes. The *Instrument.measurement* function returns a property that issues a GPIB/SCPI requests when the value is used. For example, if our "Extreme 5000" has the `*IDN?` command we can write the following property to be added above the `def __init__` line in our above example class, or added to the class after the fact as in the code here:

```
Extreme5000.id = Instrument.measurement(
   "*IDN?", """ Reads the instrument identification """
)
```

You will notice that a documentation string is required, and should be descriptive and specific.

When we use this property we will get the identification information.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.id           # Reads "*IDN?"
'Extreme 5000 identification from instrument'
```

The *Instrument.control* function extends this behavior by creating a property that you can read and set. For example, if our "Extreme 5000" has the `:VOLT?` and `:VOLT <float>` commands that are in Volts, we can write the following property.

```
Extreme5000.voltage = Instrument.control(
    ":VOLT?", ":VOLT %g",
    """ A floating point property that controls the voltage
    in Volts. This property can be set.
    """
)
```

You will notice that we use the Python string format `%g` to pass through the floating point.

We can use this property to set the voltage to 100 mV, which will execute the command and then request the current voltage.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 0.1        # Executes ":VOLT 0.1"
>>> extreme.voltage              # Reads ":VOLT?"
0.1
```

Using *Instrument.control* and *Instrument.measurement* functions, you can create a number of properties for basic measurements and controls.

The *Instrument.control* function can be used with multiple values at once, passed as a tuple. Say, we may set voltages and frequencies in our "Extreme 5000", and the the commands for this are `:VOLTFREQ?` and `:VOLTFREQ <float>,<float>`, we could use the following property:

```
Extreme5000.combination = Instrument.control(
    ":VOLTFREQ?", ":VOLTFREQ %g,%g",
    """ A floating point property that simultaneously controls the voltage
    in Volts and the frequency in Hertz. This property can be set by a tuple.
    """
)
```

In use, we could set the voltage to 200 mV, and the Frequency to 931 Hz, and read both values immediately afterwards.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.combination = (0.2, 931)        # Executes ":VOLTFREQ 0.2,931"
>>> extreme.combination                     # Reads ":VOLTFREQ?"
[0.2, 931.0]
```

The next section details additional features of *Instrument.control* that allow you to write properties that cover specific ranges, or have to map between a real value to one used in the command. Furthermore it is shown how to perform more complex processing of return values from your device.

10.4 Advanced properties

Many GPIB/SCPI commands are more restrictive than our basic examples above. The *Instrument.control* function has the ability to encode these restrictions using *validators*. A validator is a function that takes a value and a set of values, and returns a valid value or raises an exception. There are a number of pre-defined validators in *pymeasure.instruments.validators* that should cover most situations. We will cover the four basic types here.

In the examples below we assume you have imported the validators.

In many situations you will also need to process the return string in order to extract the wanted quantity or process a value before sending it to the device. The *Instrument.control*, *Instrument.measurement* and *Instrument.setting* function also provide means to achieve this.

10.4.1 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.
```

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```
    This property can be set. """,
    validator=truncated_range,
    values=[-1, 1]
)
```

Now our voltage will not raise an error, and will truncate the value to the range bounds.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 100        # Executes ":VOLT 1"
>>> extreme.voltage
1.0
```

10.4.2 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. """,
```

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```
    validator=truncated_discrete_set,
    values=[10e-3, 100e-3, 1],
    map_values=True
)
```

Now the actual GPIB/SCIP command is ":RANG 1" for a value of 100 mV, since the index of 100 mV in the values list is 1.

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 100e-3
>>> extreme.read()
'1'
>>> extreme.voltage = 1
>>> extreme.voltage
1
```

Dictionaries provide a more flexible method for mapping between real-values and those required by the instrument. If instead the `:RANG <integer>` took 1, 2, and 3 to correspond to 10 mV, 100 mV, and 1 V, then we can replace our previous control with the following.

```
Extreme5000.voltage = Instrument.control(
    ":RANG?", ":RANG %d",
    """ A floating point property that controls the voltage
    range in Volts, which takes values of 10 mV, 100 mV and 1 V.
    This property can be set. """,
    validator=truncated_discrete_set,
    values={10e-3:1, 100e-3:2, 1:3},
    map_values=True
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.voltage = 10e-3
>>> extreme.read()
'1'
>>> extreme.voltage = 100e-3
>>> extreme.voltage
0.1
```

The dictionary now maps the keys to specific values. The values and keys can be any type, so this can support properties that use strings:

```
Extreme5000.channel = Instrument.control(
    ":CHAN?", ":CHAN %d",
    """ A string property that controls the measurement channel,
    which can take the values X, Y, or Z.
    """,
    validator=strict_discrete_set,
    values={'X':1, 'Y':2, 'Z':3},
    map_values=True
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.channel = 'X'
>>> extreme.read()
'1'
>>> extreme.channel = 'Y'
>>> extreme.channel
'Y'
```

As you have seen, the *Instrument.control* function can be significantly extended by using validators and maps.

10.4.4 Processing of set values

The *Instrument.control*, and *Instrument.setting* allow a keyword argument *set_process* which must be a function that takes a value after validation and performs processing before value mapping. This function must return the processed value. This can be typically used for unit conversions as in the following example:

```
Extreme5000.current = Instrument.setting(
    ":CURR %g",
    """ A floating point property that takes the measurement current in A
    """,
    validator=strict_range,
    values=[0, 10],
    set_process=lambda v: 1e3*v,  # convert current to mA
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.current = 1  # set current to 1000 mA
```

10.4.5 Processing of return values

Similar to *set_process* the *Instrument.control*, and *Instrument.measurement* functions allow a *get_process* argument which if specified must be a function that takes a value and performs processing before value mapping. The function must return the processed value. In analogy to the example above this can be used for example for unit conversion:

```
Extreme5000.current = Instrument.control(
    ":CURR?", ":CURR %g",
    """ A floating point property representing the measurement current in A
    """,
    validator=strict_range,
    values=[0, 10],
    set_process=lambda v: 1e3*v,  # convert to mA
    get_process=lambda v: 1e-3*v,  # convert to A
)
```

```
>>> extreme = Extreme5000("GPIB::1")
>>> extreme.current = 3.1
>>> extreme.current
3.1
```

get_process can also be used to perform string processing. Let's say your instrument returns a value with its unit which has to be removed. This could be achieved by the following code:

```
Extreme5000.capacity = Instrument.measurement(
    ":CAP?",
    """ A measurement returning a capacity in nF in the format '<cap> nF'
    """,
    get_process=lambda v: float(v.replace('nF', ''))
)
```

The same can be also achieved by the *preprocess_reply* keyword argument to *Instrument.control* or *Instrument.measurement*. This function is forwarded to `Adapter.values` and runs directly after receiving the reply from the device. One can therefore take advantage of the built in casting abilities and simplify the code accordingly:

```
Extreme5000.capacity = Instrument.measurement(
    ":CAP?",
    """ A measurement returning a capacity in nF in the format '<cap> nF'
    """,
    preprocess_reply=lambda v: v.replace('nF', '')
    # notice how we don't need to cast to float anymore
)
```

The real purpose of *preprocess_reply* is, however, for instruments where many/all properties need similar reply processing. *preprocess_reply* can be applied to all *Instrument.control* or *Instrument.measurement* properties, for example if all quantities are returned with a unit as in the example above. To avoid running into troubles for other properties this *preprocess_reply* should be clever enough to skip the processing in case it is not appropriate, for example if some identification string is returned. Typically this can be achieved by regular expression matching. In case of no match the reply is returned unchanged:

```
import re
_reg_value = re.compile(r"([-+]?[0-9]*\.?[0-9]+)\s+\w+")

def extract_value(reply):
    """ extract numerical value from reply. If none can be found the reply
    is returned unchanged.

    :param reply: reply string
    :returns: string with only the numerical value
    """
    r = _reg_value.search(reply)
    if r:
        return r.groups()[0]
    else:
        return reply

class Extreme5001(Instrument):
    """ Represents the imaginary Extreme 5001 instrument. This instrument
    sends numerical values including their units in an format "<value>
    <unit>".
    """
    capacity = Instrument.measurement(
        ":CAP?",
        """ A measurement returning a capacity in nF in the format '<cap> nF'
        """
```

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```
    )

    voltage = Instrument.measurement(
        ":VOLT?",
        """ A measurement returning a voltage in V in the format '<volt> V'
        """
    )

    id = Instrument.measurement(
        "*idn?",
        """ The identification of the instrument.
        """
    )

    def __init__(self, resourceName, **kwargs):
        super().__init__(
            resourceName,
            "Extreme 5000",
            preprocess_reply=extract_value,
            **kwargs,
        )
```

In cases where the general *preprocess_reply* function should not run it can be also overwritten in the property definition:

```
Extreme5001.channel = Instrument.control(
    ":CHAN?", ":CHAN %d",
    """ A string property that controls the measurement channel,
    which can take the values X, Y, or Z.
    """,
    validator=strict_discrete_set,
    values=[1,2,3],
    preprocess_reply=lambda v: v,
)
```

Using a combination of the decribed abilities also complex communication schemes can be achieved.

CHAPTER

ELEVEN

CODING STANDARDS

In order to maintain consistency across the different instruments in the PyMeasure repository, we enforce the following standards.

11.1 Python style guides

The PEP8 style guide and PEP257 docstring conventions should be followed.

Function and variable names should be lower case with underscores as needed to seperate words. CamelCase should only be used for class names, unless working with Qt, where its use is common.

There are no plans to support type hinting in PyMeasure code. This adds a lot of additional code to manage, without a clear advantage for this project. Type documentation should be placed in the docstring where not clear from the variable name.

11.2 Documentation

PyMeasure documents code using reStructuredText and the Sphinx documentation generator. All functions, classes, and methods should be documented in the code using a docstring.

11.3 Usage of getter and setter functions

Getter and setter functions are discouraged, since properties provide a more fluid experience. Given the extensive tools avalible for defining properties, detailed in the *Advanced properties* section, these types of properties are prefered.

CHAPTER

TWELVE

AUTHORS

PyMeasure was started in 2013 by Colin Jermain and Graham Rowlands at Cornell University, when it became apparent that both were working on similar Python packages for scientific measurements. PyMeasure combined these efforts and continues to gain valuable contributions from other scientists who are interested in advancing measurement software.

The following developers have contributed to the PyMeasure package:

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CHAPTER

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