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# **auspex Documentation**

***Release 2019.2***

**Auspex Developers**

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Auspex, the *automated system for python-based experiments*, is a framework for performing laboratory measurements. Auspex was developed by a group that primarily performs measurements on superconducting qubits and magnetic memory elements, but its underpinnings are sufficiently general to allow for extension to arbitrary equipment and experiments. Using several layers of abstraction, we attempt to meet the following goals:

1. Instrument drivers should be easy to write.
2. Measurement code should be flexible and reusable.
3. Data acquisition and processing should be asynchronous and reconfigurable.
4. Experiments should be adaptive, not always pre-defined.
5. Experiments should be concerned with information density, and not limited by the convenience of rectilinear sweeps.

A number of inroads towards satisfying points (1) and (2) are made by utilizing metaprogramming to reduce boilerplate code in *Instrument* drivers and to provide a versatile framework for defining an *Experiment*. For (3) we make use of the python *asyncio* library to create a graph-based measurement *Filter* pipeline through which data passes to be processed, plotted, and written to file. For (4), we attempt to mitigate the sharp productivity hits associated with experimentors having to monitor and constantly tweak the parameters of an *Experiment*. This is done by creating a simple interface that allows *Sweeps* to refine themselves based on user-defined criterion functions. Finally, for (5) we build in “unstructured” sweeps that work with parameter tuples rather than “linspace” style ranges for each parameter. The combination of (4) and (5) allows us to take beautiful phase diagrams that require far fewer points than would be required in a rectilinear, non-adaptive scheme.



# CHAPTER 1

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## Installation & Requirements

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Auspex can be cloned from GitHub:

```
git clone https://github.com/BBN-Q/auspex.git
```

And subsequently installed using pip:

```
cd auspex  
pip install -e .
```

Which will automatically fetch and install all of the requirements. If you are using an anaconda python distribution, some of the requirements should be install with *conda install* (like *ruamel\_yaml* for example). The packages enumerated in *requirements.txt* are required by Auspex.





## CHAPTER 2

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### Qubit Experiments

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Auspex is agnostic to the type of experiment being performed, but we include infrastructure for configuring and executing qubit experiments using the gate-level [QGL](#) language. In this case, auspex relies on [bbndb](#) as a database backend for sharing state and keeping track of configurations. Depending on the experiments being run, one may need to install a number of additional driver libraries.

If you're running on a system with a low file descriptor limit you may see a *ulimit* error when trying to run or simulate experiments. This will look like a *too many files error* in python. This stems from ZMQ asynchronously opening and closing a large number of files. OSX has a default limit per notebook of 256 open files. You can easily change this number at the terminal before launching a notebook: `ulimit -n 4096` or put this line in your `.bash_profile`.



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## Genealogy and Etymology

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Auspex is a synonym for an *augur*, whose role was to interpret divine will through a variety of omens. While most researchers rightfully place their faiths in the scientific method, it is not uncommon to relate to the roles of the augur. Auspex incorporates concepts from BBN's *QLab* project as well as from the *pymasure* project from Cornell University.

Contents:

### 3.1 Instrument Documentation

#### 3.1.1 Instruments

The *Instrument* class is designed to dramatically reduce the amount of boilerplate code required for defining device drivers. The following (from *picosecond.py*) amounts to the majority of the driver definition:

```
class Picosecond10070A(SCPIInstrument):
    """Picosecond 10070A Pulser"""
    amplitude = FloatCommand(scp_string="amplitude")
    delay = FloatCommand(scp_string="delay")
    duration = FloatCommand(scp_string="duration")
    trigger_level = FloatCommand(scp_string="level")
    period = FloatCommand(scp_string="period")
    frequency = FloatCommand(scp_string="frequency",
                             aliases=['freq'])
    offset = FloatCommand(scp_string="offset")
    trigger_source = StringCommand(scp_string="trigger",
                                   allowed_values=["INT", "EXT", "GPIB"])

    def trigger(self):
        self.interface.write("*TRG")
```

Each of the Commands is converted into the relevant driver code as detailed below.

## Commands

The *Command* class variables are parsed by the *MetaInstrument* metaclass, and automatically expanded into setters and getters (as appropriate) and a *property* that gives convenient access to commands. For example, the following *Command*:

```
frequency = FloatCommand(scp_string='frequency')
```

will be expanded into the following equivalent set of class methods:

```
def get_frequency(self):
    return float(self.interface.query('frequency?'))
def set_frequency(self, value):
    self.interface.write('frequency {:E}'.format(value))
@property
def frequency(self):
    return self.get_frequency()
@frequency.setter
def frequency(self, value):
    self.set_frequency(value)
```

Instruments with consistent command syntax (which number fewer than one might hope) lend themselves to extremely concise drivers. Using additional keyword arguments such as `allowed_values`, `aliases`, and `value_map` allows for more advanced commands to be specified without the usual driver fluff. Full documentation can be found in the API reference.

## Property Access

Property access gives us a convenient way of interacting with instrument values. In the following example we construct an instance of the `Picosecond10070A` class and fire off a number of pulses:

```
pspl = Picosecond10070A("GPIB0::24::INSTR")

pspl.amplitude = 0.944          # Using setter
print("Trigger delay is: ", pspl.delay) # Using getter

for dur in 1e-9*np.arange(1, 11, 0.5):
    pspl.duration = dur
    pspl.trigger()
    time.sleep(0.05)
```

Properties present certain risks alongside their convenience: running `instr.falter_slop = 18.0` will produce no errors (since it's perfectly reasonable Python) despite the user having intended to set the `filter_slope` value. As such, we actually lock the class dictionary after parsing and initialization, and will produce errors informing you of your spelling creativities.

## 3.2 Experiment Documentation

### 3.2.1 Scripting

Instantiating a few *Instrument* classes as described in the relevant documentation provides us with an environment sufficient to perform any sort of measurement. Let us revisit our simple example with a few added instruments, and also add a few software averages to our measurement.:

```

pspl = Picosecond10070A("GPIB0::24::INSTR") # Pulse generator
mag = AMI430("192.168.5.109") # Magnet controller
keith = Keithley2400("GPIB0::25::INSTR") # Source meter

pspl.amplitude = 0.944 # V
mag.field = 0.010 # T
time.sleep(0.1) # Stableize

resistance_values = []
for dur in 1e-9*np.arange(1, 11, 0.05):
    pspl.duration = dur
    pspl.trigger()
    time.sleep(0.05)
    resistance_values.append([keith.resistance for i in range(5)])

avg_res_vals = np.mean(resistance, axis=0)

```

We have omitted a number of configuration commands for brevity. The above script works perfectly well if we always perform the exact same measurement, i.e. we hold the field and pulse amplitude fixed but vary its duration. This is normally an unrealistic restriction, since the experimenter more often than not will want to repeat the same fundamental measurement for any number of sweep conditions.

### 3.2.2 Defining Experiments

Therefore, we recommend that users package their measurements into *Experiments*, which provide the opportunity for re-use.:

```

class SwitchingExperiment(Experiment):
    # Control parameters
    field = FloatParameter(default=0.0, unit="T")
    pulse_duration = FloatParameter(default=5.0e-9, unit="s")
    pulse_voltage = FloatParameter(default=0.1, unit="V")

    # Output data connectors
    resistance = OutputConnector()

    # Constants
    samples = 5

    # Instruments, connections aren't made until run_sweeps called
    pspl = Picosecond10070A("GPIB0::24::INSTR")
    mag = AMI430("192.168.5.109")
    keith = Keithley2400("GPIB0::25::INSTR")

    def init_instruments(self):
        # Instrument initialization goes here, and is run
        # automatically by run_sweeps

        # Assign methods to parameters
        self.field.assign_method(self.mag.set_field)
        self.pulse_duration.assign_method(self.pspl.set_duration)
        self.pulse_voltage.assign_method(self.pspl.set_voltage)

        # Create hooks for relevant delays
        self.pulse_duration.add_post_push_hook(lambda: time.sleep(0.05))
        self.pulse_voltage.add_post_push_hook(lambda: time.sleep(0.05))

```

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```

self.field.add_post_push_hook(lambda: time.sleep(0.1))

def init_streams(self):
    # Establish the "intrinsic" data dimensions
    # run by run_sweeps.
    ax = DataAxis("samples", range(self.samples))
    self.resistance.add_axis(ax)

def run(self):
    # This is the inner loop, which is run for each set of
    # sweep parameters by run_sweeps. Data is pushed out
    # to the world through the output connectors.
    pspl.trigger()
    self.resistance.push(keith.resistance)

```

Here the control parameters, data flow, and the central measurement “kernel” have crystallized into separate entities. To run the same experiment as was performed above, we add a *sweep* to the experiment:

```

# Define a 1D sweep
exp = SwitchingExperiment()
exp.add_sweep(exp.pulse_duration, 1e-9*np.arange(1, 11, 0.05))
exp.run_sweeps()

```

but we can at this point sweep any *Parameter* or a combination thereof:

```

# Define a 2D sweep
exp = SwitchingExperiment()
exp.add_sweep(exp.field, np.arange(-0.01, 0.015, 0.005))
exp.add_sweep(exp.pulse_voltage, np.linspace(0.1, 1.0, 20))
exp.run_sweeps()

```

These sweeps can be based on *Parameter* tuples in order to accomodate non-rectilinear sweeps, and can be made adaptive by specifying convergence criteria that can modifying the sweeps on the fly. Full documentation is provided here. The time spent writing a full *Experiment* often pays dividends in terms of flexibility.

### 3.2.3 The Measurement Pipeline

The central `run` method of an *Experiment* should not need to worry about file IO and plotting, nor should we bake common analysis routines (filtering, plotting, etc.) into the code that is only responsible for taking data. Auspex relegates these tasks to the measurement pipeline, which provides dataflow such as that in the image below.

Each block is referred to as a *node* of the experiment graph. Data flow is assumed to be acyclic, though auspex will not save you from yourself if you attempt to circumvent this restriction. Data flow can be one-to-many, but not many-to-one. Certain nodes, such as *correlators* may take multiple inputs, but they are always wired to distinct input connectors. There are a number of advantages to representing processing and analysis as graphs, most of which stem from the ease of reconfiguration. We have even developed a specialized tool, *Quince*, that provides a graphical interfaces for modifying the contents and connectivity of the graph.

Finally, we stress data is streamed asynchronously across the graph. Each node processes data as it is received, though many types of nodes must wait until enough data has accumulated to perform their stated functions.

#### Connectors, Streams, and Descriptors

*OutputConnectors* are “ports” on the experiments through which all measurement data flows. As mentioned above, a single *OutputConnector* can send data to any number of subsequent filter nodes. Each such connection consists of a

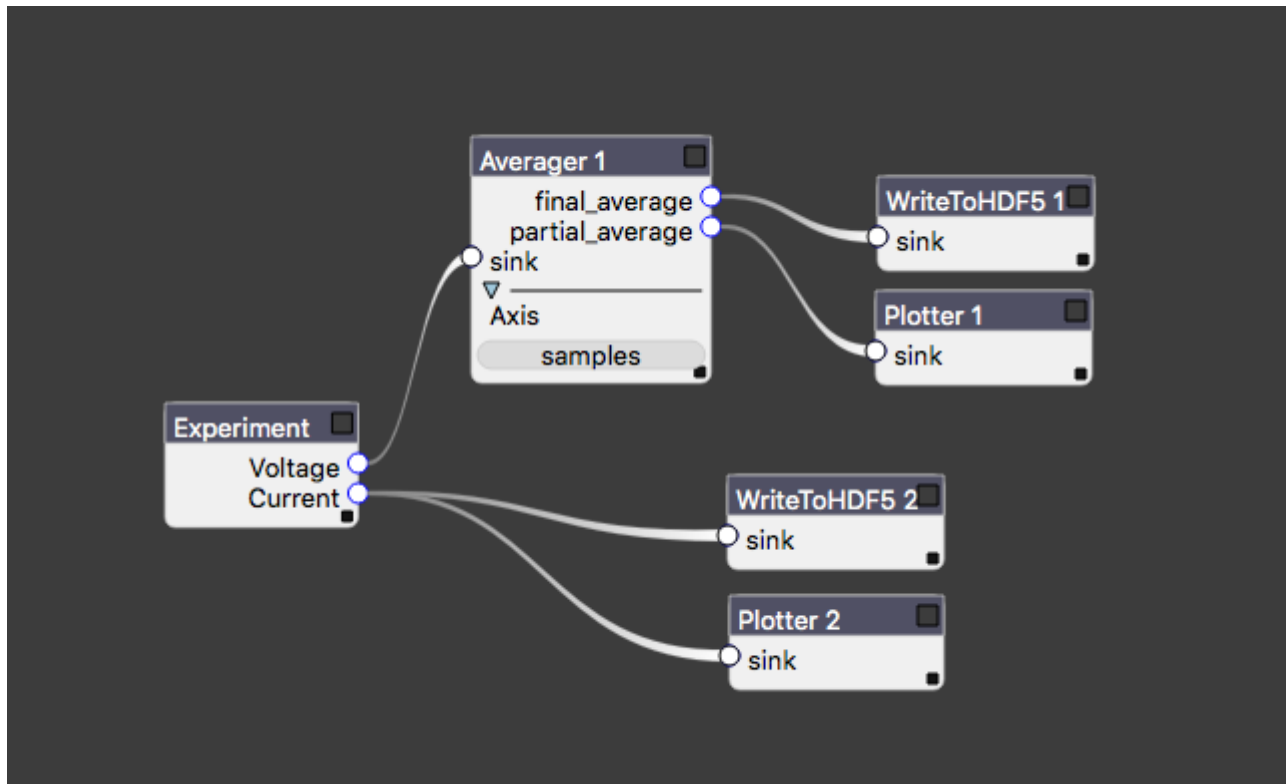


Fig. 1: An example of measurement dataflow starting from the *Experiment* at left.

*DataStream*, which contains an asyncio-compatible queue for shuttling data. Since data is streamed, rather than passed as tidy arrays, all data streams are described by a *DataStreamDescriptor* that describes the dimensionality of the data.

A *DataStreamDescriptor* contains a list of *Axes*, which contain a list of the points in the axis. These axes may be “intrinsic,” as in the case of the `DataAxis("samples", range(self.samples))` axis added in the `init_streams` method above. An axis may also be a *SweepAxis*, which is added to all descriptors automatically when you add a sweep to an experiment. Thus, assuming we’re using the 2D sweep from the example above, data emitted by the experiment is described by the following axes,:

```
[DataAxis("samples", range(5)),
SweepAxis("field", np.arange(-0.01, 0.015, 0.005)),
SweepAxis("pulse_voltage", np.linspace(0.1, 1.0, 20))]
```

Importantly, there is no requirement for rectilinear sweeps, which was one of our design goals. Back on the experiment graph, each node can modify this *DataStreamDescriptor* for downstream data: e.g. an averaging node (such as that in the figure above) that is set to average over the “samples” axis will send out data described by the axes

```
[SweepAxis("field", np.arange(-0.01, 0.015, 0.005)),
SweepAxis("pulse_voltage", np.linspace(0.1, 1.0, 20))]
```

Nodes such as data writers are, of course, written such that they store all of the axis information alongside the data. To define our filter pipeline we instantiate the nodes and then we pass a list of “edges” of the graph to the experiment

```
exp = SwitchingExperiment()
write = WriteToHDF5("filename.h5")
avg = Averager(axis='samples')
links = [(exp.resistance, avg.sink),
```

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```
(avg.final_average, write.sink)]
exp.set_graph(links)
```

Since this is rather tedious to do manually for large sets of nodes, tools like *Quince* and *PyQLab* can be used to lessen the burden.

### 3.2.4 Running Experiments in Jupyter Notebooks

You should do this.

## 3.3 Sweep Documentation

Sweeping in measurement software is often a very rigid affair. Typical parameter sweeps take the form

```
for this in range(10):
    for that in np.linspace(30.3, 100.6, 27):
        set_this(this)
        set_that(that)
        measure_everything()
```

A few questions arise at this point:

1. Is there any reason to use a rectangular grid of points?
2. Am I wasting time if features aren't uniformly distributed over this grid?
3. What if our range wasn't sufficient to capture the desired data?
4. What if we didn't get good enough statistics?

To tackle (1), there are some clear reasons to measure on a rectilinear grid. First of all, it is extremely convenient. Also, if you expect that regions of interest (ROI) are distributed evenly across your measurement domain then this seems like a reasonable choice. Finally there are simple aesthetic considerations: image plots look much better when they are fill a rectangular domain rather than leaving swaths of NaNs strewn the periphery of your image.

Point (2) is really an extension of (1): if you are looking at data that follows  $\sin(x) * \sin(y)$  then the information density is practically constant across the domain. If you are looking at a crooked phase transition in a binary system, then the vast majority of your points will be wasted on regions with very low information content. Take the following phase diagrams for an MRAM cell's switching probability.

#### 3.3.1 Structured Sweeps

#### 3.3.2 Unstructured Sweeps

## 3.4 Qubit Experiments

Auspex and QGL comprise BBN's qubit measurement software stack. Both packages utilize the underlying database schema provided by *bbndb* that allows them to easily share state and allows the user to take advantage of versioned measurement configurations.



### 3.4.1 Important Changes in the BBN-Q Software Ecosystem

There has been a recent change in how we do things:

1. Both Auspex and QGL now utilize the bbndb backend for configuration information. YAML has been completely dropped as it was too freeform and error prone.
2. HDF5 has been dropped as the datafile format for auspex and replaced with a simple numpy-backed binary format with metadata.
3. HDF5 has also been dropped as the sequence file format for our APS1 and APS2 arbitrary pulse sequencers, a simple binary format prevails here as well.
4. The plot server and client have been decoupled from the main auspex code and now are executed independently. They can even be run remotely!
5. Bokeh has been replaced with bqplot where possible, which has much better data throughput.

### 3.4.2 Tutorials

The best way to gain experience is to follow through with these tutorials:

#### Example Q1: Configuring a Channel Library from Scratch

This example notebook shows how, using QGL, one can configure a measurement system. All configuration occurs within the notebook, but interfaces with the QGL `ChannelLibrary` object that uses the bbndb package database backend.

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#### Creating a Channel Library

The `AWGDir` environment variable is used to indicate where QGL will store its output sequence files. First we load the QGL module. It defaults to a temporary directory as provided by Python's `tempfile` module.

```
[1]: from QGL import *
```

AWG\_DIR environment variable not defined. Unless otherwise specified, using temporary\_↵  
↵directory for AWG sequence file outputs.

Next we instantiate the channel library. By default bbndb will use an sqlite database at the location specified by the `BBN_DB` environment variable, but we override this behavior below in order to use a temporary in memory database for testing purposes.

```
[2]: cl = ChannelLibrary(":memory:")
```

Creating engine...

The channel library has a number of convenience functions defined for create instruments and qubits, as well as functions to define the relationships between them. Let us create a qubit first:

```
[3]: q1 = cl.new_qubit("q1")
```

Later on we will see how to save and load other versions of the channel library, so remember that *this reference will become stale if other library versions are loaded*. After creation it is safest to refer to channels using keyword syntax on the channel library, i.e. `cl["q1"]`. We'll discuss this more later. Now we create some instrumentation: AWGs, a digitizer, and some microwave sources

```
[4]: # Most calls required label and address
aps2_1 = cl.new_APS2("BBNAPS1", address="192.168.5.101")
aps2_2 = cl.new_APS2("BBNAPS2", address="192.168.5.102")
dig_1  = cl.new_X6("X6_1", address=0)
```

There is more general syntax for arbitrary instruments:

```
[5]: # Label, instrument type, address, and an additional config parameter
h1 = cl.new_source("Holz1", "HolzworthHS9000", "HS9004A-009-1", power=-30)
h2 = cl.new_source("Holz2", "HolzworthHS9000", "HS9004A-009-2", power=-30)
```

Now we want to define which instruments control what.

```
[6]: # Qubit q1 is controlled by AWG aps2_1, and uses microwave source h1
cl.set_control(q1, aps2_1, generator=h1)
# Qubit q1 is measured by AWG aps2_2 and digitizer dig_1, and uses microwave source h2
cl.set_measure(q1, aps2_2, dig_1.ch(1), generator=h2)
# The AWG aps2_1 is the master AWG, and distributes a synchronization trigger on its
↪second marker channel
cl.set_master(aps2_1, aps2_1.ch("m2"))
```

These objects are linked to one another, and belong to a relational database. Therefore once can easily drill through the heirarchy using typical “dot” attribute access. i.e. we can configure the sidebanding of q1 using the following:

```
[7]: cl["q1"].measure_chan.frequency = 10e6
```

All of the object above have been added to the current database session, but must be committed in order to be made permanent. That can be done as follows:

```
[8]: cl.commit()
```

At this point the channel database is automatically saved to the “working” copy. All of the current channel libraries can be listed (along with their ID and date stamp) with:

```
[9]: cl.ls()

<IPython.core.display.HTML object>
```

The channel library will attempt to prevent you from creating redundant objects, e.g.:

```
[10]: q1 = cl.new_qubit("q1")

A database item with the name q1 already exists. Updating parameters of this existing
↪item instead.
```

```
[11]: cl.set_measure(q1, aps2_2, dig_1.ch(1), generator=h2)

The measurement M-q1 already exists: using this measurement.
The Receiver trigger ReceiverTrig-q1 already exists: using this channel.
```

Let’s plot the pulse files for a Rabi sequence (giving a directory for storing AWG information).

```
[12]: q1.measure_chan.pulse_params['length'] = 1000e-9
q1.measure_chan.trig_chan.pulse_params['length'] = 100e-9

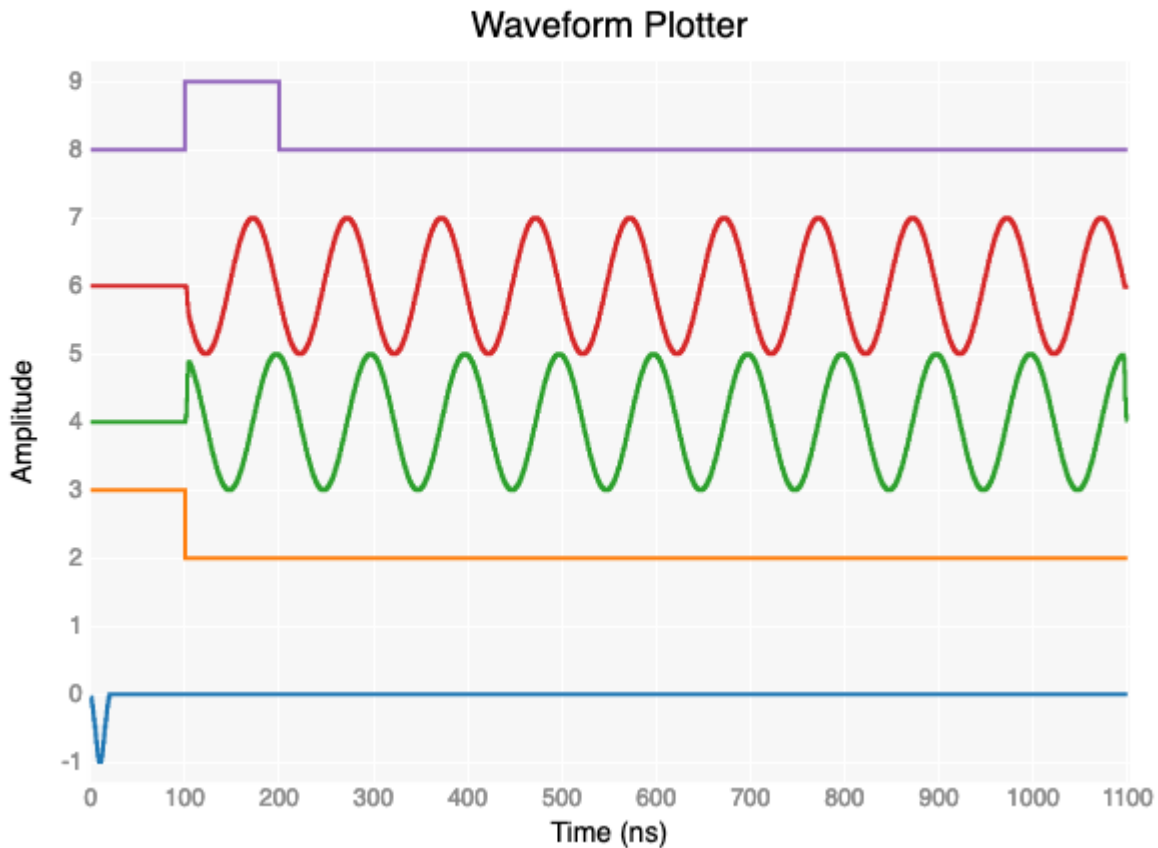
[13]: plot_pulse_files(RabiAmp(cl["q1"], np.linspace(-1, 1, 11)), time=True)
```

```
Compiled 11 sequences.
```

```
VBox(children=(IntSlider(value=1, description='Segment', max=11, min=1),  
↩Figure(animation_duration=50, axes=[A...
```

Compiled 11 sequences.

Segment



[ ]:

### Example Q2: Save and Loading Channel Library Versions

This example notebook shows how one may save and load versions of the channel library.

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### Saving Channel Library Versions

We initialize the channel library as shown in tutorial *Q1*:

```
[2]: from QGL import *
```

```
cl = ChannelLibrary(":memory:")
q1 = cl.new_qubit("q1")
aps2_1 = cl.new_APS2("BBNAPS1", address="192.168.5.101")
aps2_2 = cl.new_APS2("BBNAPS2", address="192.168.5.102")
dig_1 = cl.new_X6("X6_1", address=0)
h1 = cl.new_source("Holz1", "HolzworthHS9000", "HS9004A-009-1", power=-30)
h2 = cl.new_source("Holz2", "HolzworthHS9000", "HS9004A-009-2", power=-30)
cl.set_control(q1, aps2_1, generator=h1)
cl.set_measure(q1, aps2_2, dig_1.ch(1), generator=h2)
cl.set_master(aps2_1, aps2_1.ch("m2"))
cl["q1"].measure_chan.frequency = 0e6
cl.commit()
```

A database item with the name q1 already exists. Updating parameters of this existing item instead.

A database item with the name BBNAPS1 already exists. Updating parameters of this existing item instead.

A database item with the name BBNAPS2 already exists. Updating parameters of this existing item instead.

A database item with the name X6\_1 already exists. Updating parameters of this existing item instead.

A database item with the name Holz1 already exists. Updating parameters of this existing item instead.

A database item with the name Holz2 already exists. Updating parameters of this existing item instead.

Let us save this channel library for posterity:

```
[3]: cl.save_as("NoSidebanding")
```

Now we adjust some parameters and save another version of the channel library

```
[4]: cl["q1"].measure_chan.frequency = 50e6
      cl.commit()
      cl.save_as("50MHz-Sidebanding")
```

Maybe we forgot to change something. No worries! We can just update the parameter and create a new copy.

```
[5]: cl["q1"].pulse_params['length'] = 400e-9
      cl.commit()
      cl.save_as("50MHz-Sidebanding")
      cl.ls()
```

```
<IPython.core.display.HTML object>
```

We see the various versions of the channel library here. Note that the user is *always* modifying the working version of the database: all other versions are archival, but they can be *restored* to the current working version as shown below.

## Loading Channel Library Versions

Let us load a previous version of the channel library, noting that the former value of our parameter is restored in the working copy. **CRUCIAL POINT:** do not use the old reference `q1`, which is no longer pointing to the database since the working db has been replaced with the saved version. Instead use dictionary access `cl["q1"]` on the channel library to return the first qubit:

```
[6]: cl.load("NoSidebanding")
      cl["q1"].measure_chan.frequency
```

```
[6]: 0.0
```

Now let's load the *second oldest* version of the 50MHz-sidebanding library:

```
[7]: cl.load("50MHz-Sidebanding", -1)
      cl["q1"].pulse_params['length'], cl["q1"].measure_chan.frequency
```

```
[7]: (2e-08, 50000000.0)
```

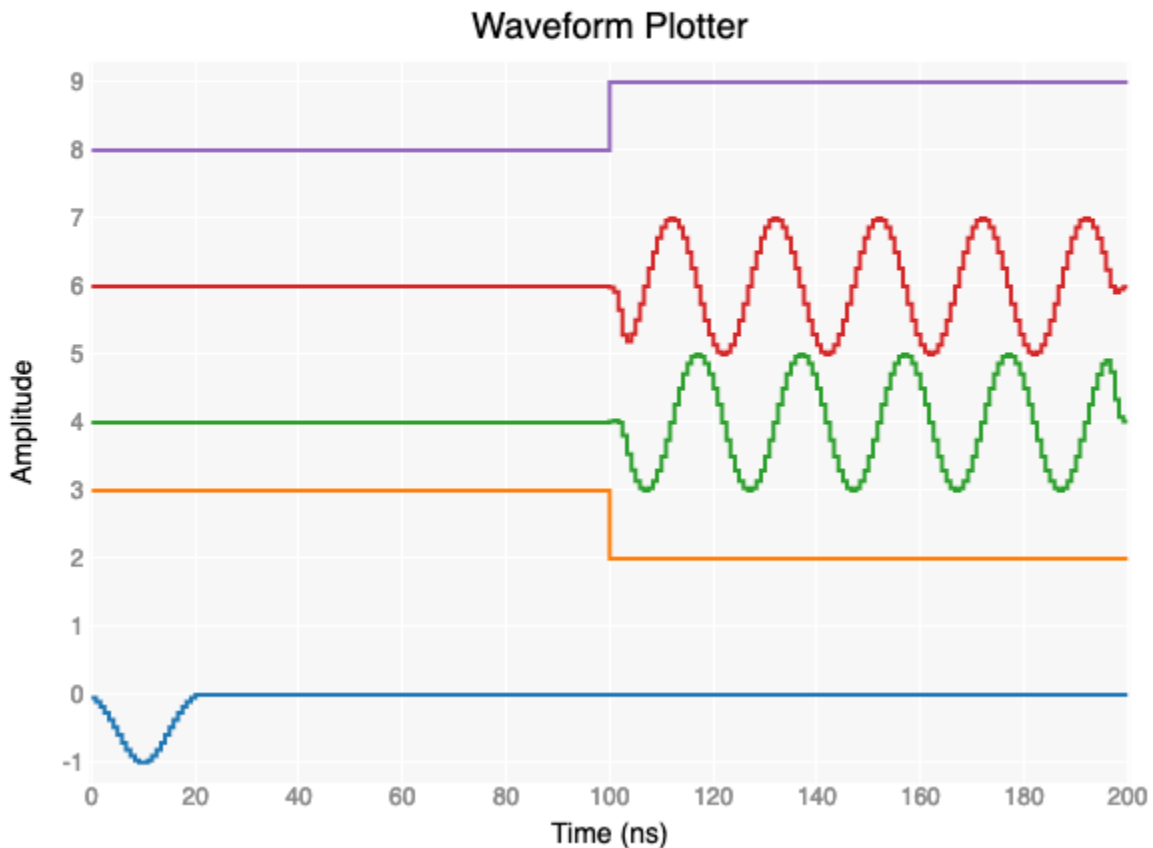
```
[8]: # q1 = QubitFactory("q1")
      plot_pulse_files(RabiAmp(cl["q1"], np.linspace(-1, 1, 11)), time=True)
```

Compiled 11 sequences.

```
VBox(children=(IntSlider(value=1, description='Segment', max=11, min=1),
  ↳Figure(animation_duration=50, axes=[A...
```

Compiled 11 sequences.

Segment



```
[9]: cl.ls()
<IPython.core.display.HTML object>
```

```
[10]: cl.rm("NoSidebanding")
```

```
[11]: cl.ls()
<IPython.core.display.HTML object>
```

```
[12]: cl.rm("50MHz-Sidebanding")
```

```
[13]: cl.ls()
<IPython.core.display.HTML object>
```

### Example Q3: Managing the Filter Pipeline

This example notebook shows how to use the `PipelineManager` to modify the signal processing on qubit data.

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We initialize a slightly more advanced channel library:

```
[1]: from QGL import *

cl = ChannelLibrary(":memory:")

# Create five qubits and supporting hardware
for i in range(5):
    q1 = cl.new_qubit(f"q{i}")
    cl.new_APS2(f"BBNAPS2-{2*i+1}", address=f"192.168.5.{101+2*i}")
    cl.new_APS2(f"BBNAPS2-{2*i+2}", address=f"192.168.5.{102+2*i}")
    cl.new_X6(f"X6_{i}", address=0)
    cl.new_source(f"Holz{2*i+1}", "HolzworthHS9000", f"HS9004A-009-{2*i}", power=-30)
    cl.new_source(f"Holz{2*i+2}", "HolzworthHS9000", f"HS9004A-009-{2*i+1}", power=-
→30)
    cl.set_control(cl[f"q{i}"], cl[f"BBNAPS2-{2*i+1}"], generator=cl[f"Holz{2*i+1}"])
    cl.set_measure(cl[f"q{i}"], cl[f"BBNAPS2-{2*i+2}"], cl[f"X6_{i}"][1],
→generator=cl[f"Holz{2*i+2}"])

cl.set_master(cl["BBNAPS2-1"], cl["BBNAPS2-1"].ch("m2"))
cl.commit()

AWG_DIR environment variable not defined. Unless otherwise specified, using temporary
→directory for AWG sequence file outputs.
```

### Creating the Default Filter Pipeline

```
[2]: from auspex.qubit import *

auspex-WARNING: 2019-04-04 13:38:24,127 ----> You may not have the libusb backend;
→please install it!
auspex-WARNING: 2019-04-04 13:38:24,298 ----> Could not load channelizer library;
→falling back to python methods.
```

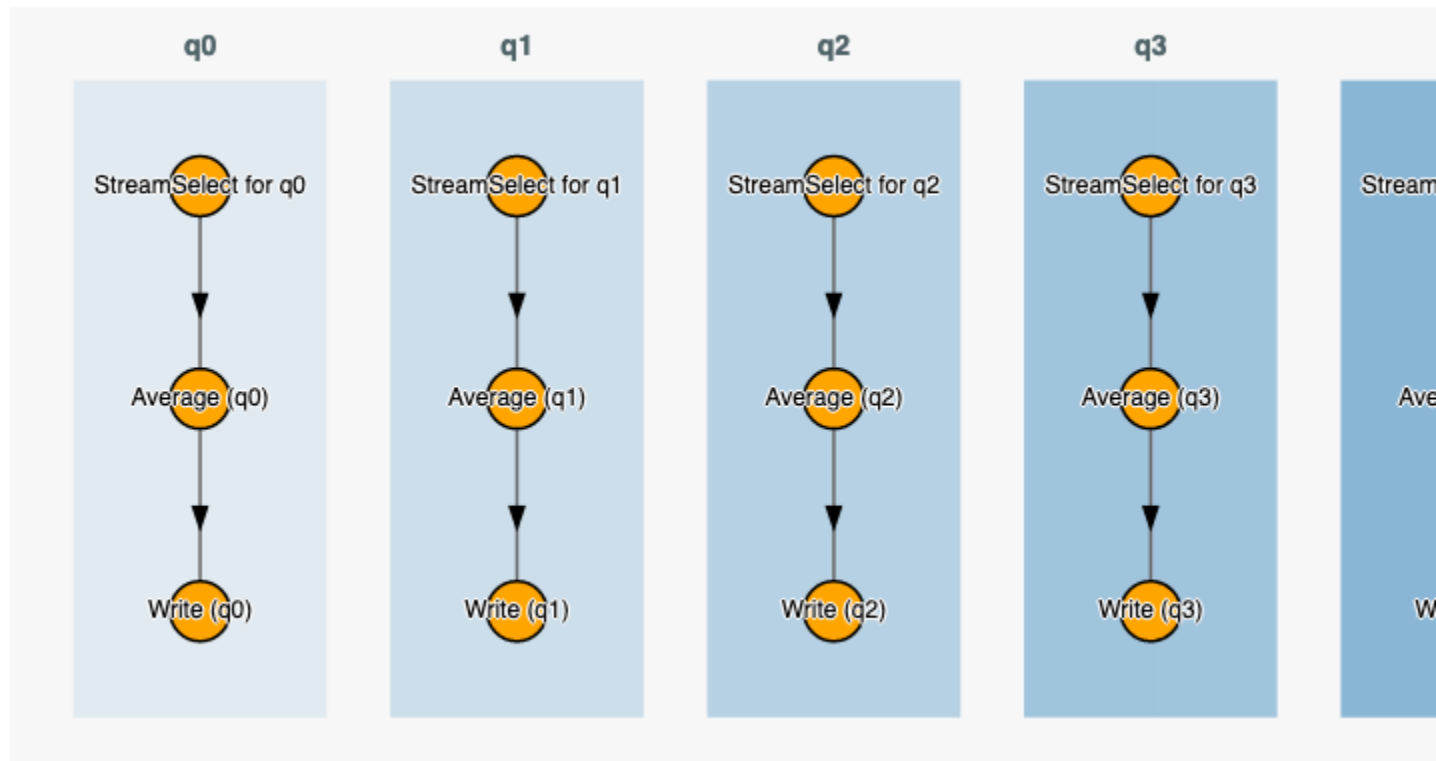
The `PipelineManager` is analogous to the `ChannelLibrary` inasmuch as it provides the user with an interface to programmatically modify the filter pipeline, and to save and load different versions of the pipeline.

```
[3]: pl = PipelineManager()

auspex-INFO: 2019-04-04 13:38:24,641 ----> Could not find an existing pipeline.
↳Please create one.
```

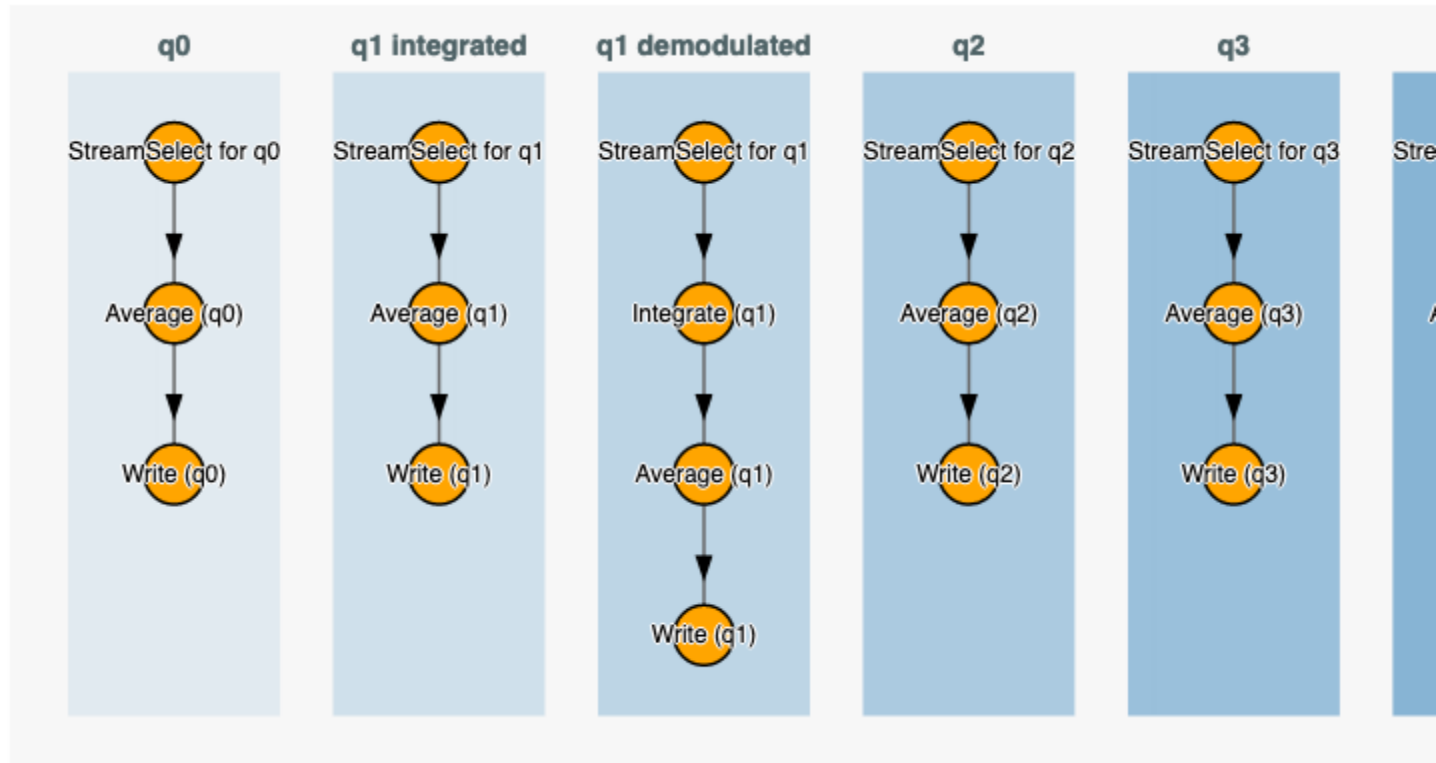
Pipelines are fairly predictable, and will provide some subset of the functionality of demodulating, integrating, average, and writing to file. Some of these can be done on hardware, some in software. The `PipelineManager` can guess what the user wants for a particular qubit by inspecting which equipment has been assigned to it using the `set_measure` command for the `ChannelLibrary`. For example, this `ChannelLibrary` has defined X6-1000M cards for readout, and the description of this instrument indicates that the highest level available stream is integrated. Thus, the `PipelineManager` automatically inserts the remaining averager and writer.

```
[ ]: pl.create_default_pipeline()
pl.show_pipeline()
```



Sometimes, for debugging purposes, one may wish to add multiple pipelines per qubit. Additional pipelines can be added explicitly by running:

```
[ ]: pl.add_qubit_pipeline("q1", "demodulated")
pl.show_pipeline()
```



```
[6]: pl.ls()
<IPython.core.display.HTML object>
```

We can print the properties of a single node

```
[9]: pl["q1 integrated"].print()
<IPython.core.display.HTML object>
```

We can print the properties of individual filters or subgraphs:

```
[10]: pl.print("q1 integrated")
<IPython.core.display.HTML object>
```

Dictionary access is provided to allow drilling down into the pipelines. One can use the specific label of a filter or simple its type in this access mode:

```
[11]: pl["q1 integrated"]["Average"]["Write"].filename = "new.h5"
pl.print("q1 integrated")
<IPython.core.display.HTML object>
```

Here uncommitted changes are shown. This can be rectified in the standard way:

```
[12]: cl.commit()
pl.print("q1 integrated")
<IPython.core.display.HTML object>
```

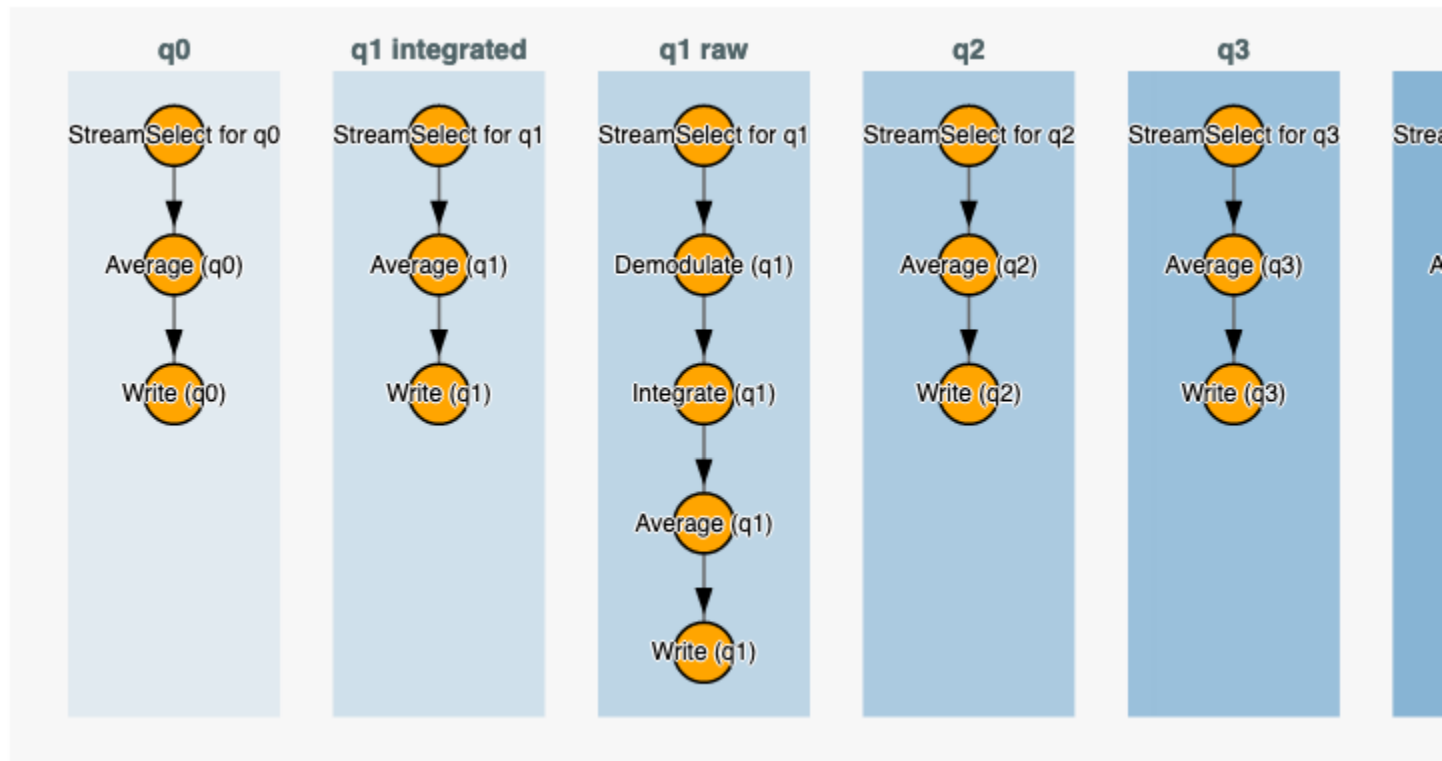


## Programmatic Modification of the Pipeline

Some simple convenience functions allow the use to easily specify complex pipeline structures.

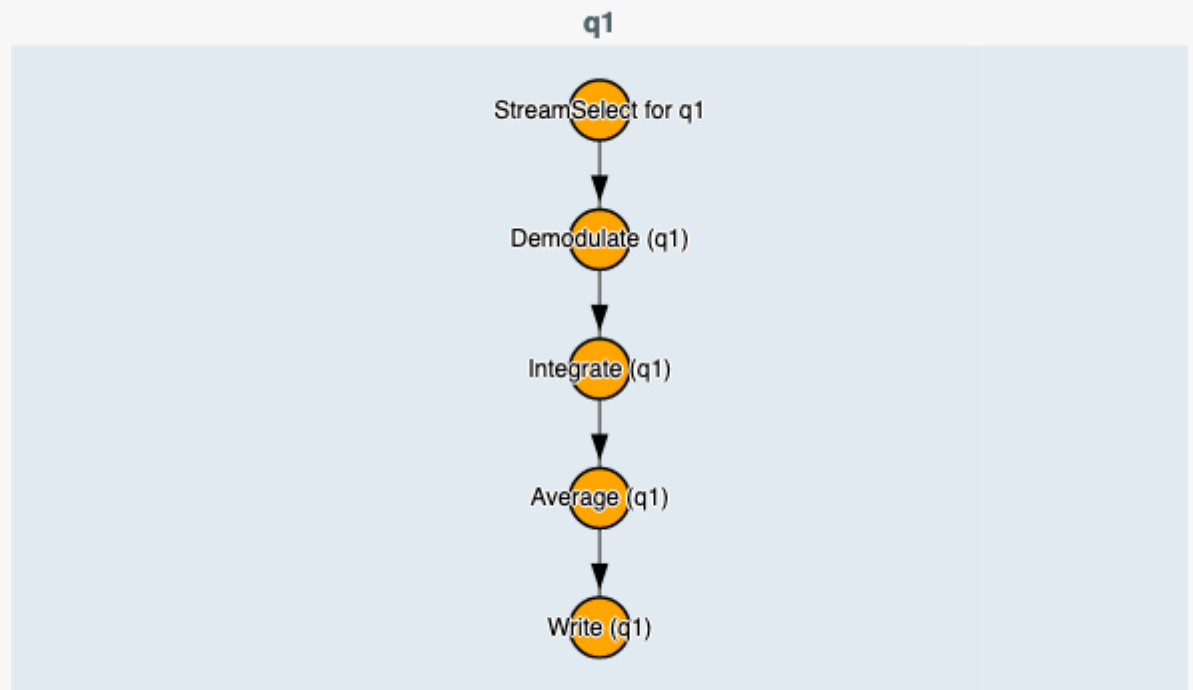
```
[13]: pl.commit()
      pl.save_as("simple")
      pl["q1 demodulated"].clear_pipeline()
      pl["q1 demodulated"].stream_type = "raw"
      pl.recreate_pipeline()
      # pl["q1"]["blub"].show_pipeline()
```

```
[ ]: pl.show_pipeline()
```

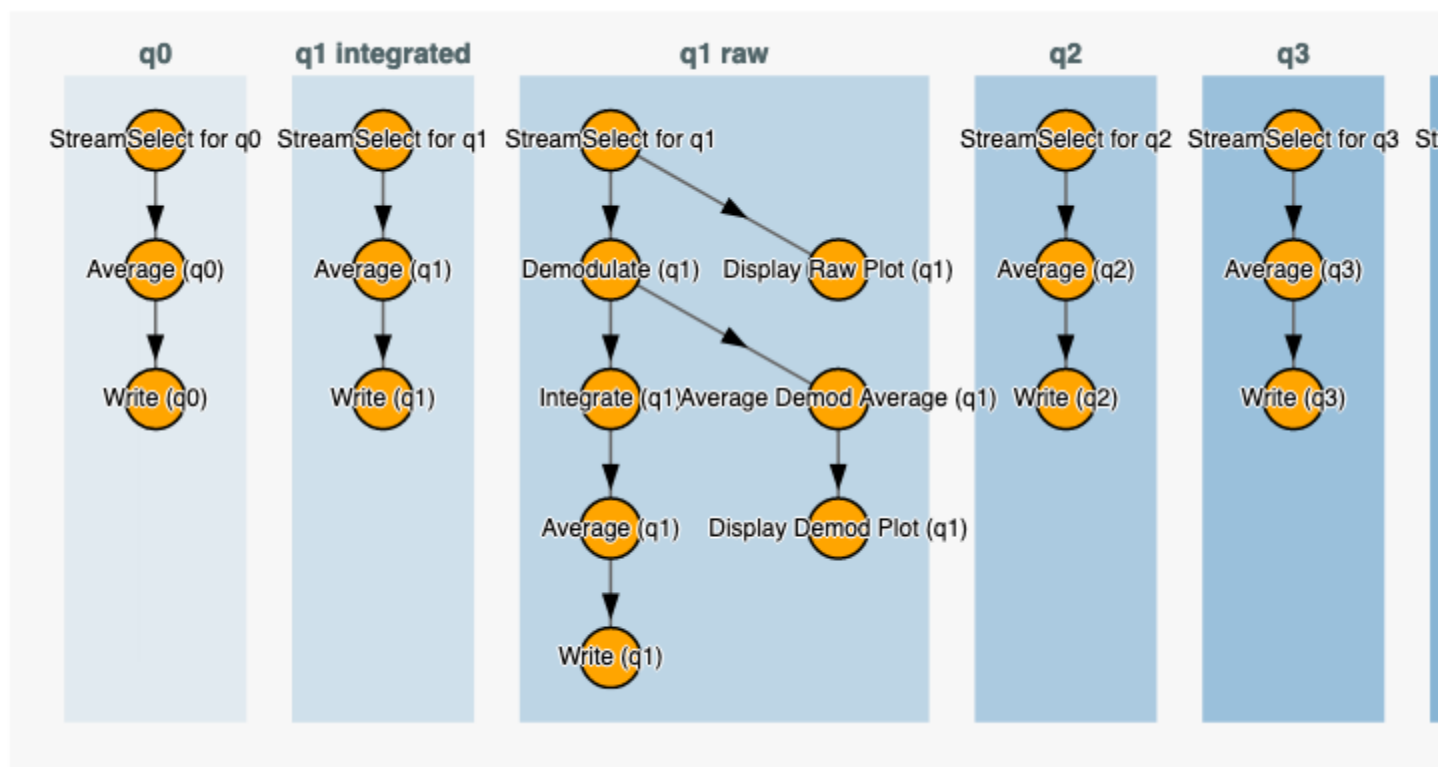


Note the name change. We refer to the pipeline by the stream type of the first element.

```
[ ]: pl["q1 raw"].show_pipeline()
```



```
[ ]: pl["q1 raw"].add(Display(label="Raw Plot"))
pl["q1 raw"]["Demodulate"].add(Average(label="Demod Average")).add(Display(label=
↪ "Demod Plot"))
pl.show_pipeline()
```

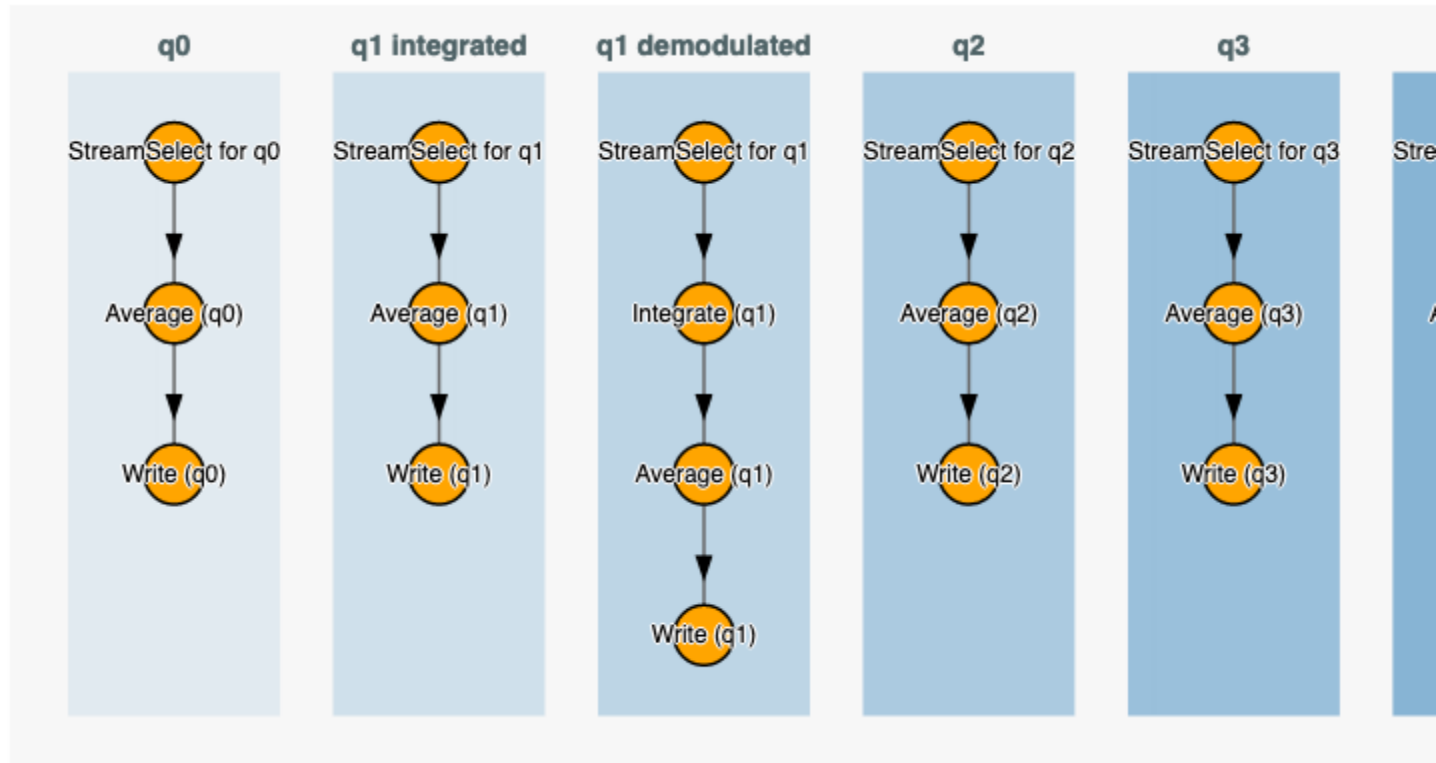


As with the ChannelLibrary we can list save, list, and load versions of the filter pipeline.

```
[17]: pl.session.commit()
      pl.save_as("custom")
      pl.ls()

<IPython.core.display.HTML object>
```

```
[ ]: pl.load("simple")
      pl.show_pipeline()
```



```
[19]: pl.ls()
<IPython.core.display.HTML object>
```

### Pipeline examples:

Below are some examples of how more complicated pipelines can be constructed. Defining these as functions allows for quickly changing the structure of the data pipeline depending on the experiment being done. It also improves reproducibility and documents pipeline parameters. For example, to change the pipeline and check its construction,

```
pl = create_tomo_pipeline(save_rr=True)
pl.show_pipeline()
```

Hopefully the examples below will show you some of the more advanced things that can be done with the data pipelines in Auspex.

```
[ ]: # a basic pipeline that uses 'raw' data at the beginning of the data processing
def create_standard_pipeline():
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'], cl['q3']))
    for ql in ['q2', 'q3']:
        qb = cl[ql]
        pl[ql].clear_pipeline()
        pl[ql].stream_type = "raw"
        pl[ql].create_default_pipeline(buffers=False)
        pl[ql].if_freq = qb.measure_chan.autodyne_freq
        pl[ql]["Demodulate"].frequency = qb.measure_chan.autodyne_freq
        pl[ql]["Demodulate"]["Integrate"].simple_kernel = True
        pl[ql]["Demodulate"]["Integrate"].box_car_start = 3e-7
```

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```

    pl[ql]["Demodulate"]["Integrate"].box_car_stop = 1.3e-6
    #pl[ql]["Demodulate"]["Integrate"].add(Write(label="RR-Writer", groupname=ql+
    ↪"-int"))
    pl[ql]["Demodulate"]["Integrate"]["Average"].add(Display(label=ql+" - Final_
    ↪Average", plot_dims=0))
    pl[ql]["Demodulate"]["Integrate"]["Average"].add(Display(label=ql+" - Partial_
    ↪Average", plot_dims=0), connector_out="partial_average")
    return pl

# if you only want to save data integrated with the single-shot filter
def create_integrated_pipeline(save_rr=False, plotting=True):
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'],cl['q3']))
    for ql in ['q2', 'q3']:
        qb = cl[ql]
        pl[ql].clear_pipeline()
        pl[ql].stream_type = "integrated"
        pl[ql].create_default_pipeline(buffers=False)
        pl[ql].kernel = f"{ql.upper()}_SSF_kernel.txt"
        if save_rr:
            pl[ql].add(Write(label="RR-Writer", groupname=ql+"-rr"))
        if plotting:
            pl[ql]["Average"].add(Display(label=ql+" - Final Average", plot_dims=0))
            pl[ql]["Average"].add(Display(label=ql+" - Partial Average", plot_dims=0),
            ↪ connector_out="partial_average")

    return pl

# create to single-shot fidelity pipelines for two qubits
def create_fidelity_pipeline():
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'],cl['q3']))
    for ql in ['q2', 'q3']:
        qb = cl[ql]
        pl[ql].clear_pipeline()
        pl[ql].stream_type = "raw"
        pl[ql].create_default_pipeline(buffers=False)
        pl[ql].if_freq = qb.measure_chan.autodyne_freq
        pl[ql]["Demodulate"].frequency = qb.measure_chan.autodyne_freq
        pl[ql].add(FidelityKernel(save_kernel=True, logistic_regression=False, set_
    ↪threshold=True, label=f"Q{ql[-1]}_SSF"))
        pl[ql]["Demodulate"]["Integrate"].simple_kernel = True
        pl[ql]["Demodulate"]["Integrate"].box_car_start = 3e-7
        pl[ql]["Demodulate"]["Integrate"].box_car_stop = 1.3e-6
        #pl[ql]["Demodulate"]["Integrate"].add(Write(label="RR-Writer", groupname=ql+
    ↪"-int"))
        pl[ql]["Demodulate"]["Integrate"]["Average"].add(Display(label=ql+" - Final_
    ↪Average", plot_dims=0))
        pl[ql]["Demodulate"]["Integrate"]["Average"].add(Display(label=ql+" - Partial_
    ↪Average", plot_dims=0), connector_out="partial_average")
    return pl

# optionally save the demoded data
def create_RR_pipeline(plot=False, write_demods=False):
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'],cl['q3']))
    for ql in ['q2', 'q3']:

```

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```

qb = cl[q1]
pl[q1].clear_pipeline()
pl[q1].stream_type = "raw"
pl[q1].create_default_pipeline(buffers=False)
pl[q1].if_freq = qb.measure_chan.autodyne_freq
pl[q1]["Demodulate"].frequency = qb.measure_chan.autodyne_freq
if write_demods:
    pl[q1]["Demodulate"].add(Write(label="demod-writer", groupname=q1+"-demod
↪"))
    pl[q1]["Demodulate"]["Integrate"].simple_kernel = True
    pl[q1]["Demodulate"]["Integrate"].box_car_start = 3e-7
    pl[q1]["Demodulate"]["Integrate"].box_car_stop = 1.3e-6
    pl[q1]["Demodulate"]["Integrate"].add(Write(label="RR-Writer", groupname=q1+"-
↪int"))
    if plot:
        pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" -
↪Final Average", plot_dims=0))
        pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" -
↪Partial Average", plot_dims=0), connector_out="partial_average")
    return pl

# save everything... using data buffers instead of writing to file
def create_full_pipeline(buffers=True):
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'],cl['q3']), buffers=True)
    for q1 in ['q2', 'q3']:
        qb = cl[q1]
        pl[q1].clear_pipeline()
        pl[q1].stream_type = "raw"
        pl[q1].create_default_pipeline(buffers=buffers)
        if buffers:
            pl[q1].add(Buffer(label="raw_buffer"))
        else:
            pl[q1].add(Write(label="raw-write", groupname=q1+"-raw"))
        pl[q1].if_freq = qb.measure_chan.autodyne_freq
        pl[q1]["Demodulate"].frequency = qb.measure_chan.autodyne_freq
        if buffers:
            pl[q1]["Demodulate"].add(Buffer(label="demod_buffer"))
        else:
            pl[q1]["Demodulate"].add(Write(label="demod_write", groupname=q1+"-demod
↪"))
        pl[q1]["Demodulate"]["Integrate"].simple_kernel = True
        pl[q1]["Demodulate"]["Integrate"].box_car_start = 3e-7
        pl[q1]["Demodulate"]["Integrate"].box_car_stop = 1.6e-6
        if buffers:
            pl[q1]["Demodulate"]["Integrate"].add(Buffer(label="integrator_buffer"))
        else:
            pl[q1]["Demodulate"]["Integrate"].add(Write(label="int_write",
↪groupname=q1+"-integrated"))
        pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" - Final
↪Average", plot_dims=0))
        pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" - Partial
↪Average", plot_dims=0), connector_out="partial_average")
        return pl

# A more complicated pipeline with a correlator
# These have to be coded more manually because the correlator needs all the
↪correlated channels specified.

```

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```

# Note that for tomography you're going to want to save the data variance as well,
→ though this can be calculated
# after the fact if you save the raw shots (save_rr).
def create_tomo_pipeline(save_rr=False, plotting=True):
    pl = PipelineManager()
    pl.create_default_pipeline(qubits=(cl['q2'], cl['q3']))

    for ql in ['q2', 'q3']:
        qb = cl[ql]
        pl[ql].clear_pipeline()
        pl[ql].stream_type = "integrated"
        pl[ql].create_default_pipeline(buffers=False)
        pl[ql].kernel = f"{ql.upper()}_SSF_kernel.txt"
        pl[ql]["Average"].add(Write(label='var'), connector_out='final_variance')
        pl[ql]["Average"]["var"].groupname = ql + '-main'
        pl[ql]["Average"]["var"].datasetname = 'variance'
        if save_rr:
            pl[ql].add(Write(label="RR-Writer", groupname=ql+"-rr"))
        if plotting:
            pl[ql]["Average"].add(Display(label=ql+" - Final Average", plot_dims=0))
            pl[ql]["Average"].add(Display(label=ql+" - Partial Average", plot_dims=0),
→ connector_out="partial_average")

        # needed for two-qubit state reconstruction
        pl.add_correlator(pl['q2'], pl['q3'])
        pl['q2']['Correlate'].add(Average(label='corr'))
        pl['q2']['Correlate']['Average'].add(Write(label='corr_write'))
        pl['q2']['Correlate']['Average'].add(Write(label='corr_var'), connector_out=
→ 'final_variance')
        pl['q2']['Correlate']['Average']['corr_write'].groupname = 'correlate'
        pl['q2']['Correlate']['Average']['corr_var'].groupname = 'correlate'
        pl['q2']['Correlate']['Average']['corr_var'].datasetname = 'variance'

    return pl

```

## Example Q4: Running a Basic Experiment

This example notebook shows how run Auspex qubit experiments using the fake data interface.

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First we ask auspex to run in dummy mode, which avoids loading instrument drivers.

```
[1]: import auspex.config as config
     config.auspex_dummy_mode = True
```

```
[ ]: from QGL import *
     from auspex.qubit import *
     import matplotlib.pyplot as plt
     %matplotlib inline
```

Channel library setup

```
[3]: cl = ChannelLibrary(":memory:")
     pl = PipelineManager()
```

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```

q1 = cl.new_qubit("q1")
aps2_1 = cl.new_APS2("BBNAPSa", address="192.168.2.4", trigger_interval=200e-6)
aps2_2 = cl.new_APS2("BBNAPSb", address="192.168.2.2")
dig_1 = cl.new_X6("Dig_1", address="1", sampling_rate=500e6, record_length=1024)
h1 = cl.new_source("Holz_1", "HolzworthHS9000", "HS9004A-009-1", reference='10MHz',
↳power=-30)
h2 = cl.new_source("Holz_2", "HolzworthHS9000", "HS9004A-009-2", reference='10MHz',
↳power=-30)

cl.set_measure(q1, aps2_1, dig_1.ch(1), trig_channel=aps2_1.ch("m2"), gate=False,
↳generator=h1)
cl.set_control(q1, aps2_2, generator=h2)
cl.set_master(aps2_1, aps2_1.ch("m1"))
cl["q1"].measure_chan.frequency = 0e6
cl["q1"].measure_chan.autodyne_freq = 10e6

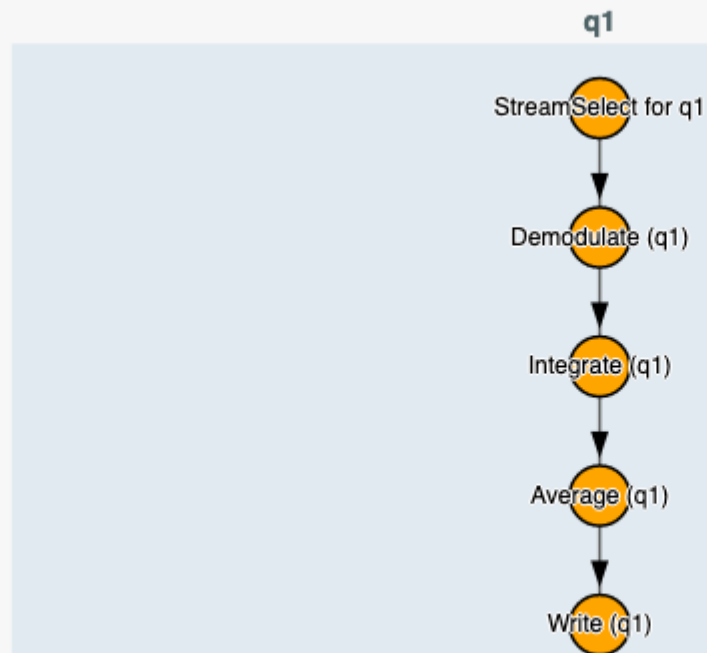
auspex-INFO: 2019-04-04 17:36:36,136 ----> Could not find an existing pipeline.
↳Please create one.

```

### Pipeline setup

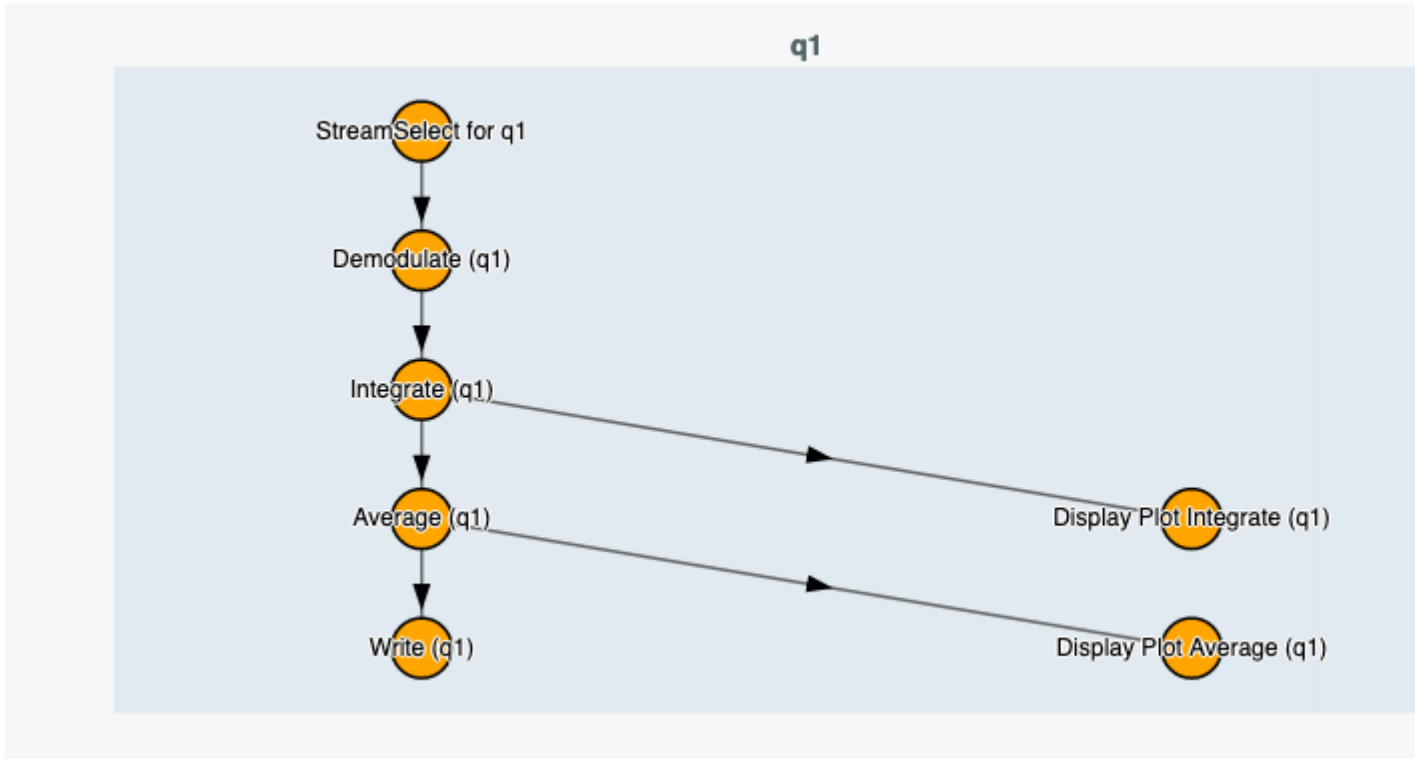
```
[4]: pl.create_default_pipeline()
```

```
[ ]: pl["q1"].stream_type = "raw"
pl.recreate_pipeline(buffers=False)
pl.show_pipeline()
```





```
[ ]: pl["q1"]["Demodulate"]["Integrate"]["Average"].add(Display(label="Plot Average", plot_
→dims=1), connector_out="partial_average")
pl["q1"]["Demodulate"]["Integrate"].add(Display(label="Plot Integrate", plot_dims=1))
pl.show_pipeline()
```



Initialize software demodulation parameters. If these are not properly configured than the `Channelizer` filter will report ‘insufficient decimation’ or other errors. The integration boxcar parameters are then defined.

```
[19]: demod = pl["q1"]["Demodulate"]
demod.frequency = cl["q1"].measure_chan.frequency
demod.decimation_factor = 16
```

```
[20]: integ = pl["q1"]["Demodulate"]["Integrate"]
integ.box_car_start = 0.2e-6
integ.box_car_stop= 1.9e-6
```

## Taking Fake Data

Now we create a simple experiment, but ask the digitizer to emit fake data of our choosing. This is useful for debugging one’s configuration without having access to hardware. The `set_fake_data` method loads the fake dataset into the indicated digitizer’s driver. The digitizer driver automatically chooses the nature of it’s output depending on whether receiver channels are raw, demodulated, or integrated.

```
[21]: amps = np.linspace(-1,1,51)
exp = QubitExperiment(RabiAmp(q1,amps),averages=50)
exp.set_fake_data(dig_1, np.cos(np.linspace(0, 2*np.pi,51)))
exp.run_sweeps()
```

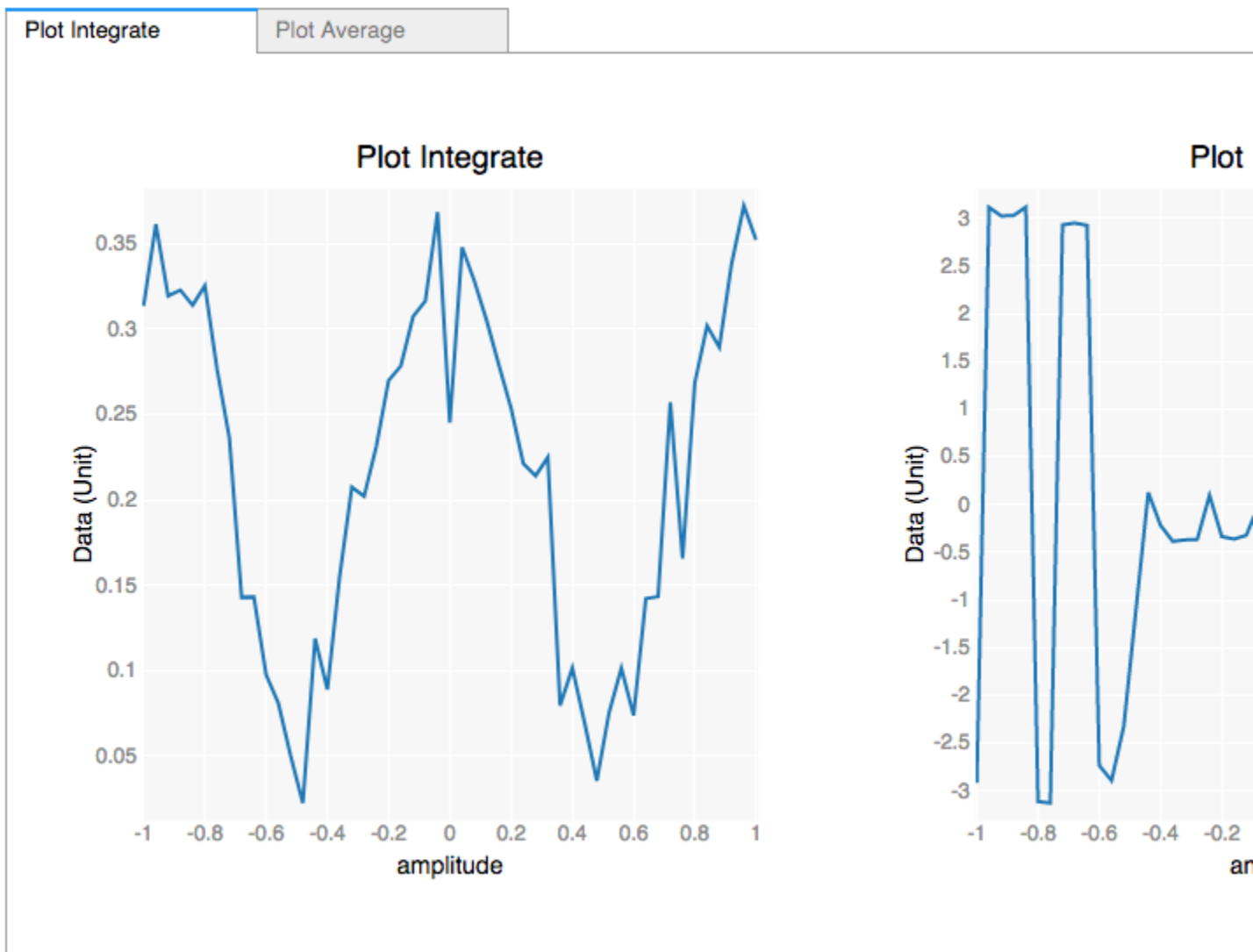
```
Compiled 51 sequences.
Qubit('q1') has 1

VBox(children=(IntProgress(value=0, bar_style='success', description='Digitizer Data_
→q1-row:', max=652800, sty...

auspex-INFO: 2019-04-04 17:38:10,603 ----> Connection established to plot server.
```

## Plotting the Results in the Notebook

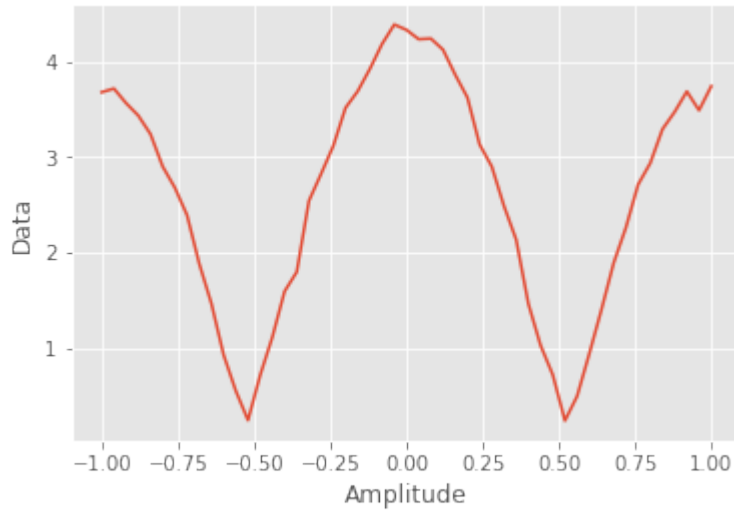
```
[ ]: exp.get_final_plots()
```



## Loading the Data Files and Plot Manually

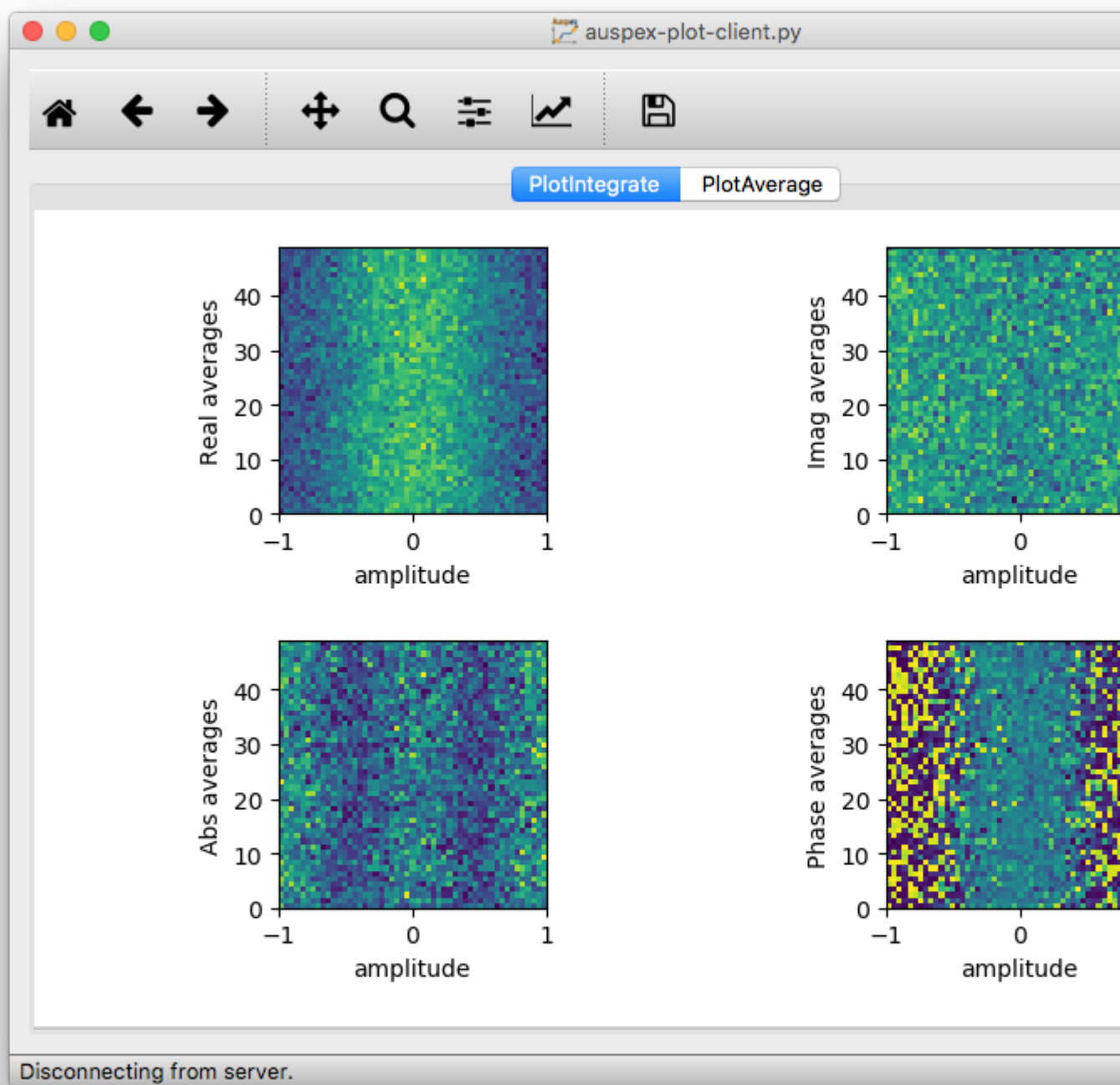
```
[35]: data, desc = exp.outputs_by_qubit["q1"][0].get_data()
```

```
[36]: plt.plot(desc["amplitude"], np.abs(data))  
plt.xlabel("Amplitude"); plt.ylabel("Data");
```



### Plotting and the Plot Server & Client

The Display nodes in the filter pipeline are turned into live plotters. In the `auspex/Utils` directory one can find `auspex-plot-server.py` and `auspex-plot-client.py`. The server, which should be executed first, acts as a data router and can accept multiple clients (and even multiple concurrent Auspex runs). The client polls the server to see whether any plots are available. If so, it grabs their descriptions and constructs a tab for each Display filter. The plots are updated as new data becomes available, and will look something like this:



For every execution of `run_sweeps` on an experiment, a new plot will be opened. In the plot client menus, however, the user can close all previous plots as well as choose to ‘Auto Close Plots’, which closes any previous plots before opening another.

## Remote Usage

The plot server and client can be run remotely, as can the Jupyter notebooks one expects to run. By running the following ssh port-forwarding command:

```
ssh -R 7761:localhost:7761 -R 7762:localhost:7762 -L 8889:my.host.com:8888 -l   
↪username my.host.com
```

You could connect to a remotely running Jupyter notebook on port 8888 locally at port 8889, and then (after starting `auspex-plot-server.py` and `auspex-plot-client.py` on your local machine) watch new plots appear in a live window on your local machine.

This presumes one does not have unfettered network access to the remote host, in which case ssh tunneling is not necessary. Currently the plotter and client assume they are all connecting on localhost, but we will create a convenient interface for their configuration soon.

## Monitoring Changes in the Channel Library

The session keeps track of what values have changed without being committed, e.g.:

```
[ ]: cl.session.commit()
      cl.session.dirty
```

Everything is in sync with the database. Now we modify some property:

```
[ ]: aps2_1.ch(1).amp_factor = 0.95
      cl.session.dirty
```

We see that things have changed that haven't been committed to the database. This can be rectified with another commit, or optionally a rollback!

```
[ ]: cl.session.rollback()
      aps2_1.ch(1).amp_factor
```

## Example Q5: Experiment Sweeps

This example notebook shows how to add sweeps to Auspex qubit experiments

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```
[1]: import auspex.config as config
      config.auspex_dummy_mode = True
```

```
[2]: from QGL import *
      from auspex.qubit import *
```

```
AWG_DIR environment variable not defined. Unless otherwise specified, using temporary_
↪directory for AWG sequence file outputs.
```

```
auspex-WARNING: 2019-04-02 14:33:37,114 ----> Could not load channelizer library;_
↪falling back to python methods.
```

Channel library setup

```
[3]: cl = ChannelLibrary(":memory:")
pl = PipelineManager()

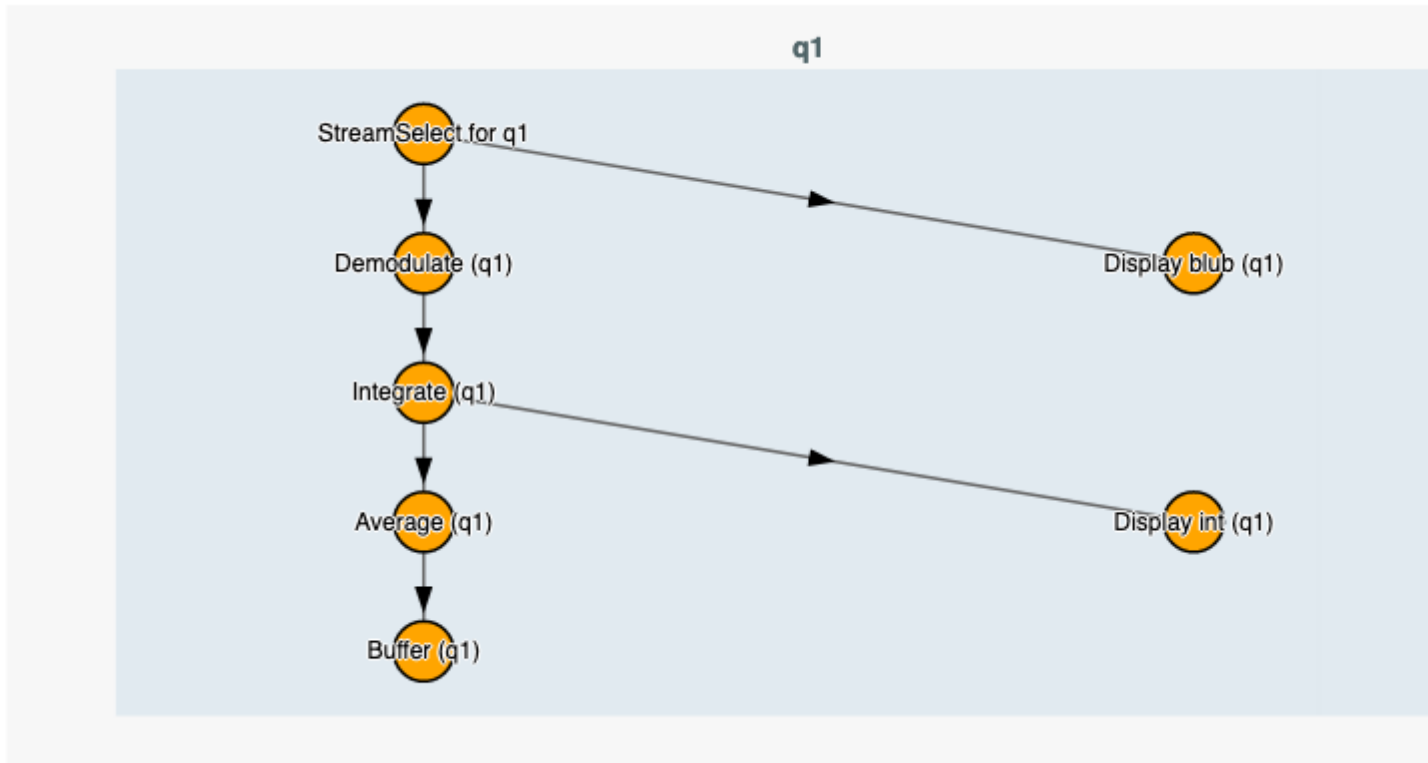
q1 = cl.new_qubit("q1")
aps2_1 = cl.new_APS2("BBNAPSa", address="192.168.2.4", trigger_interval=200e-6)
aps2_2 = cl.new_APS2("BBNAPSb", address="192.168.2.2")
dig_1 = cl.new_Alazar("Alazar_1", address="1", sampling_rate=500e6, record_
↳length=1024)
h1 = cl.new_source("Holz_1", "HolzworthHS9000", "HS9004A-009-1", reference='10MHz',
↳power=-30)
h2 = cl.new_source("Holz_2", "HolzworthHS9000", "HS9004A-009-2", reference='10MHz',
↳power=-30)

cl.set_measure(q1, aps2_1, dig_1.ch("1"), trig_channel=aps2_1.ch("m2"), gate=False,
↳generator=h1)
cl.set_control(q1, aps2_2, generator=h2)
cl.set_master(aps2_1, aps2_1.ch("m1"))
cl["q1"].measure_chan.frequency = 0e6
cl["q1"].measure_chan.autodyne_freq = 10e6

auspex-INFO: 2019-04-02 14:33:37,563 ----> Could not find an existing pipeline.
↳Please create one.
```

Pipeline setup: **Take Note:** we use the `buffers` keyword argument to automatically generate buffers instead of writers. This is sometimes convenient if you don't require data to be written to file. It becomes immediately available in the notebook after running!

```
[ ]: pl.create_default_pipeline(buffers=True)
pl["q1"].add(Display(label="blub"))
pl["q1"]["Demodulate"]["Integrate"].add(Display(label="int", plot_dims=1))
pl.show_pipeline()
```



Initialize software demodulation parameters. If these are not properly configured than the Channelizer filter will report ‘insufficient decimation’ or other errors. The integration boxcar parameters are then defined.

```
[14]: demod = pl["q1"]["Demodulate"]
      demod.frequency = cl["q1"].measure_chan.frequency
      demod.decimation_factor = 16
```

```
[15]: integ = pl["q1"]["Demodulate"]["Integrate"]
      integ.box_car_start = 0.2e-6
      integ.box_car_stop= 1.9e-6
```

### Adding experiment sweeps

Once a QubitExperiment has been created, we can programmatically add sweeps as shown here.

```
[ ]: lengths = np.linspace(20e-9, 2020e-9, 31)
      exp = QubitExperiment(RabiWidth(q1,lengths),averages=50)
      exp.set_fake_data(dig_1, np.exp(-lengths/1e-6)*np.cos(1e7*lengths))
      # exp.add_qubit_sweep(q1,"measure", "frequency", np.linspace(6.512e9, 6.522e9, 11))
      exp.run_sweeps()
```

Compiled 21 sequences.

Digitizer Data q1: [REDACTED]  
 Digitizer Data q1:  
 q1 measure frequency: [REDACTED]

We fetch the data and data descriptor directly from the buffer. The data is automatically reshaped to match the experiment axes, and the descriptor enumerates all of the values of these axes for convenience plotting, etc..

```
[21]: data, descriptor = exp.outputs_by_qubit["q1"][0].get_data()

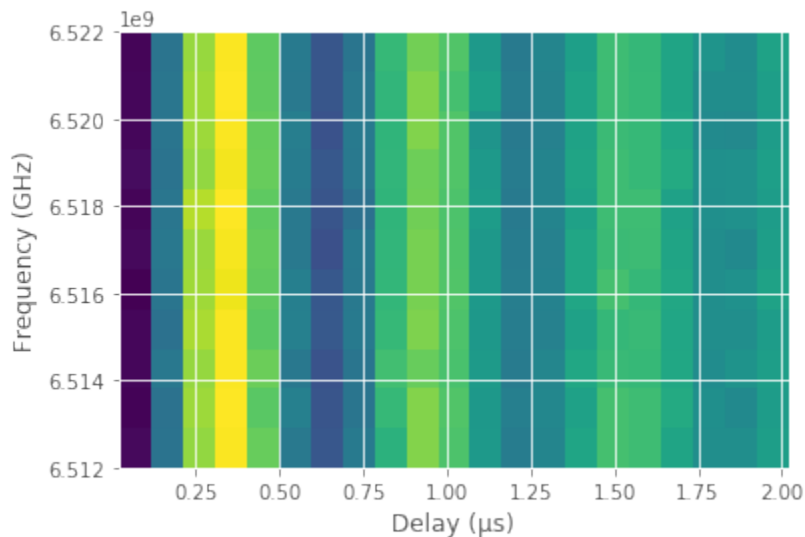
[22]: descriptor.axes
[22]: [<SweepAxis(name=q1 measure frequency,length=11,unit=None,value=6522000000.0,
↪unstructured=False>,
      <DataAxis(name=delay, start=0.02, stop=2.02, num=21, unit=us)>]

[23]: data.shape
[23]: (11, 21)
```

We even include a convenience extent function conforming to the infinitely forgettable matplotlib format.

```
[24]: import matplotlib.pyplot as plt
      %matplotlib inline

      plt.imshow(np.real(data), aspect='auto', extent=descriptor.extent())
      plt.xlabel("Delay (μs)")
      plt.ylabel("Frequency (GHz)");
```



## Adding Multiple Sweeps

An arbitrary number of sweeps can be added. For example:

```
[25]: exp = QubitExperiment(RabiWidth(q1,lengths),averages=50)
      exp.add_qubit_sweep(q1,"measure", "frequency", np.linspace(6.512e9, 6.522e9, 5))
      exp.add_qubit_sweep(q1,"measure", "amplitude", np.linspace(0.0, 1.0, 21))

      Compiled 21 sequences.
```

If we inspect the internal representation of the “output connector” into which the instrument driver will dump its data, we can see all of the axes it contains.



```
[26]: exp.output_connectors["q1"].descriptor.axes
[26]: [<SweepAxis(name=q1 measure amplitude,length=21,unit=None,value=0.0,
↳unstructured=False>,
      <SweepAxis(name=q1 measure frequency,length=5,unit=None,value=6512000000.0,
↳unstructured=False>,
      <DataAxis(name=averages, start=0, stop=49, num=50, unit=None)>,
      <DataAxis(name=delay, start=0.02, stop=2.02, num=21, unit=us)>,
      <DataAxis(name=time, start=0.0, stop=2.046e-06, num=1024, unit=None)>]
```

The `DataAxis` entries are “baked in” using hardware looping, while the `SweepAxis` entries are external software loops facilitated by Auspex.

## Example Q6: Calibrations

This example notebook shows how to use the pulse calibration framework.

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```
[ ]: from QGL import *
     from auspex.qubit import *
```

We use a pre-existing database containing a channel library and pipeline we have established.

```
[3]: cl = ChannelLibrary("my_config")
     pl = PipelineManager()
```

## Calibrating Mixers

The APS2 requires mixers to upconvert to qubit and cavity frequencies. We must tune the offset of these mixers and the amplitude factors of the quadrature channels to ensure the best possible results. We repeat the definition of the spectrum analyzer here, assuming that the LO driving this instrument is present in the channel library as `spec_an_LO`.

```
[ ]: spec_an = cl.new_spectrum_analyzer("SpecAn", "ASRL/dev/ttyACM0::INSTR", cl["spec_an_LO"]
↳)
     cal = MixerCalibration(q2, spec_an, mixer="measure")
     cal.calibrate()
```

If the plot server and client are open, then the data will be plotted along with fits from the calibration procedure. The calibration procedure automatically knows which digitizer and AWG units are needed in the process. The relevant instrument parameters are updated but not committed to the database. Therefore they may be rolled back if undesirable results are found.

## Pulse Calibrations

A simple set of calibrations is performed as follows.

```
[ ]: cals = RabiAmpCalibration(q2)
     cal.calibrate()
```

```
[ ]: cal = RamseyCalibration(q2)
     cal.calibrate()
```

Of course this is somewhat repetitive and can be sped up:

```
[ ]: cals = [RabiAmpCalibration, RamseyCalibration, Pi2Calibration, PiCalibration]
      [cal(q2).calibrate() for cal in cals]
```

## Automatic Tuneup

While we develop algorithms for fully automated tuneup, some segments of the analysis are (primitively) automated as seen below:

```
[ ]: cal = QubitTuneup(q2, f_start=5.2e9, f_stop=5.8e9, coarse_step=50e6, fine_step=0.5e6,
      ↪averages=250, amp=0.1)
      cal.calibrate()
```

## Example Q7: Single Shot Fidelity

This example notebook shows how to run single shot fidelity experiments

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```
[2]: from QGL import *
      from auspex.qubit import *

      Defaulting to temporary directory for AWG sequence file outputs.

      auspex-WARNING: 2019-03-08 10:07:30,785 ----> Could not load channelizer library;
      ↪falling back to python methods.
```

We use a pre-existing database containing a channel library and pipeline we have established.

```
[3]: cl = ChannelLibrary("my_config")
      pl = PipelineManager()
```

## Calibrating Mixers

The APS2 requires mixers to upconvert to qubit and cavity frequencies. We must tune the offset of these mixers and the amplitude factors of the quadrature channels to ensure the best possible results. We repeat the definition of the spectrum analyzer here, assuming that the LO driving this instrument is present in the channel library as `spec_an_LO`.

```
[ ]: spec_an = cl.new_spectrum_analyzer("SpecAn", "ASRL/dev/ttyACM0::INSTR", cl["spec_an_LO"]
      ↪)
      cal = MixerCalibration(q2, spec_an, mixer="measure")
      cal.calibrate()
```

If the plot server and client are open, then the data will be plotted along with fits from the calibration procedure. The calibration procedure automatically knows which digitizer and AWG units are needed in the process. The relevant instrument parameters are updated but not committed to the database. Therefore they may be rolled back if undesirable results are found.

## Example Q8: Realistic Two Qubit Tuneup and Experiments

This example notebook shows how to use APS2/X6 ecosystem to tune up a pair of qubits.

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```
[ ]: import os
os.environ['AWG_DIR'] = "./AWG"

import matplotlib
import matplotlib.pyplot as plt
import QGL.config
import auspex.config
auspex.config.AWGDir = "/home/qlab/BBN/AWG"
QGL.config.AWGDir = "/home/qlab/BBN/AWG"
auspex.config.KernelDir = "/home/qlab/BBN/Kernels"
QGL.config.KernelDir = "/home/qlab/BBN/Kernels"

%matplotlib inline

from auspex.analysis.qubit_fits import *
from auspex.analysis.helpers import *

from QGL import *
from auspex.qubit import *

#import seaborn as sns
#sns.set_style('whitegrid')
```

## Channel Library Setup

```
[ ]: # this will all be system dependent
cl = ChannelLibrary(":memory:")

q1 = cl.new_qubit("q1")
q2 = cl.new_qubit("q2")
ip_addresses = [f"192.168.4.{i}" for i in [21, 22, 23, 24, 25, 26, 28, 29]]
aps2 = cl.new_APS2_rack("Maxwell", ip_addresses, tdm_ip="192.168.4.11")
cl.set_master(aps2.px("TDM"))
dig_1 = cl.new_X6("MyX6", address=0)

dig_1.record_length = 4096

# qubit 1
AM1 = cl.new_source("AutodyneM1", "HolzworthHS9000", "HS9004A-492-1",
                    power=16.0, frequency=6.4762e9, reference="10MHz")

qlsrc = cl.new_source("qlsource", "HolzworthHS9000", "HS9004A-492-2",
                      power=16.0, frequency=4.2e9, reference="10MHz")

cl.set_measure(q1, aps2.tx(4), dig_1.channels[1], gate=False, trig_channel=aps2.tx(6).
               ↪ch("m3"), generator=AM1)
cl.set_control(q1, aps2.tx(5), generator=qlsrc)

cl["q1"].measure_chan.autodyne_freq = 11e6
cl["q1"].measure_chan.pulse_params = {"length": 3e-6,
                                       "amp": 1.0,
                                       "sigma": 1.0e-8,
                                       "shape_fun": "tanh"}
```

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```

cl["q1"].frequency = 67.0e6
cl["q1"].pulse_params = {"length": 100e-9,
                          "pi2Amp": 0.4,
                          "piAmp": 0.8,
                          "shape_fun": "drag",
                          "drag_scaling": 0.0,
                          "sigma": 5.0e-9}

#qubit 2
AM2 = cl.new_source("AutodyneM2", "HolzworthHS9000", "HS9004A-492-3",
                   power=16.0, frequency=6.4762e9, reference="10MHz")

q2src = cl.new_source("q2source", "HolzworthHS9000", "HS9004A-492-4",
                    power=16.0, frequency=4.2e9, reference="10MHz")

cl.set_measure(q2, aps2.tx(7), dig_1.channels[0], gate=False, trig_channel=aps2.tx(6).
↳ch("m3"), generator=AM2)
cl.set_control(q2, aps2.tx(8), generator=q2src)

cl["q2"].measure_chan.autodyne_freq = 11e6
cl["q2"].measure_chan.pulse_params = {"length": 3e-6,
                                       "amp": 1.0,
                                       "sigma": 1.0e-8,
                                       "shape_fun": "tanh"}

cl.commit()

```

```

[ ]: # initialize all four APS2 to linear regime
for i in range(4,8):
    aps2.tx(i).ch(1).I_channel_amp_factor = 0.5
    aps2.tx(i).ch(1).Q_channel_amp_factor = 0.5
    aps2.tx(i).ch(1).amp_factor = 1

```

```

[ ]: pl = PipelineManager()
pl.create_default_pipeline(qubits=[q1,q2])

for q1 in ['q1','q2']:
    qb = cl[q1]
    pl[q1].clear_pipeline()

    pl[q1].stream_type = "raw"

    pl[q1].create_default_pipeline(buffers=False)

    pl[q1]["Demodulate"].frequency = qb.measure_chan.autodyne_freq

    # only enable this filter when you're running single shot fidelity
    #pl[q1].add(FidelityKernel(save_kernel=True, logistic_regression=True, set_
↳threshold=True, label="Q1_SSF"))

    pl[q1]["Demodulate"]["Integrate"].box_car_start = 3e-7
    pl[q1]["Demodulate"]["Integrate"].box_car_stop = 2.3e-6

    #pl[q1].add(Display(label=q1+" - Raw", plot_dims=0))
    #pl[q1]["Demodulate"].add(Display(label=q1+" - Demod", plot_dims=0))

```

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```

pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" - Final_
↪Average", plot_dims=0))

# if you want to see partial averages:
#pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" - Partial_
↪Average", plot_dims=0), connector_out="partial_average")

#pl[q1]["Demodulate"]["Integrate"]["Average"].add(Display(label=q1+" - Partial_
↪AverageId", plot_dims=1), connector_out="partial_average")
pl.show_pipeline()

```

## Cavity Spectroscopy

```

[ ]: pf = PulsedSpec(q1, specOn=False)
plot_pulse_files(pf)

[ ]: exp = QubitExperiment(pf, averages=256)
#exp.add_qubit_sweep(q2, "measure", "frequency", np.linspace(6.38e9, 6.395e9, 51))
exp.add_qubit_sweep(q1, "measure", "frequency", np.linspace(6.424e9, 6.432e9, 45))
#exp.add_qubit_sweep(q1, "measure", "amplitude", np.linspace(0.2, 0.8, 10))
exp.run_sweeps()

[ ]: # data, desc = exp.writers[0].get_data()
# plt.plot(desc.axes[0].points, np.abs(data))

[ ]: AM1.frequency = 6.42843e9

[ ]: AM2.frequency = 6.3863e9

```

## Qubit Spectroscopy

```

[ ]: qb = q1

[ ]: qb.frequency = 0.0
qb.pulse_params['length'] = 5e-6
qb.pulse_params['shape_fun'] = "tanh"
pf = PulsedSpec(qb, specOn=True)
plot_pulse_files(pf)

[ ]: pf = PulsedSpec(qb, specOn=True)
exp = QubitExperiment(pf, averages=256)
exp.add_qubit_sweep(qb, "control", "frequency", np.linspace(5.28e9, 5.34e9, 61))
#exp.run_sweeps()

[ ]: # data, desc = exp.writers[0].get_data()
# plt.plot(desc.axes[0].points, np.abs(data))

[ ]: q1.frequency = -63e6
q1.pulse_params['length'] = 200e-9

```

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```
q1.pulse_params['shape_fun'] = "tanh"
q1.pulse_params['piAmp'] = 0.4
q1.pulse_params['pi2Amp'] = 0.2
pf = PulsedSpec(q1, specOn=True)
#plot_pulse_files(pf)
```

```
[ ]: fq = 5.26e9 #5.2525e9
q1src.frequency = fq - q1.frequency
q1.phys_chan.I_channel_amp_factor = 0.2
q1.phys_chan.Q_channel_amp_factor = 0.2
```

```
[ ]: q1src.frequency
```

```
[ ]: q2.frequency = 81e6
q2.pulse_params['length'] = 200e-9
q2.pulse_params['shape_fun'] = "tanh"
q2.pulse_params['piAmp'] = 0.4
q2.pulse_params['pi2Amp'] = 0.2
pf = PulsedSpec(q2, specOn=True)
#plot_pulse_files(pf)
```

```
[ ]: fq2 = 5.2113e9
q2src.frequency = fq2 - q2.frequency
q2.phys_chan.I_channel_amp_factor = 0.2
q2.phys_chan.Q_channel_amp_factor = 0.2
```

```
[ ]: q2src.frequency
```

## Mixer calibration

```
[ ]: salo = cl.new_source("salo", "HolzworthHS9000", "HS9004A-381-4",
                        power=10.0, frequency=6.5e9, reference="10MHz")
specAn = cl.new_spectrum_analyzer('specAn', 'ASRL/dev/ttyACM0', salo)
```

```
[ ]: from auspex.instruments import enumerate_visa_instruments, SpectrumAnalyzer
```

```
[ ]: enumerate_visa_instruments()
```

```
[ ]: # from here out, uncomment cal.calibrate() if you want to actually run the cal
cal = MixerCalibration(q1, specAn, 'control', phase_range = (-0.5, 0.5), amp_range=(0.8,
→ 1.2))
#cal.calibrate()
```

```
[ ]: # listed here only if manual adjustment is needed
```

```
q1.phys_chan.I_channel_offset = -0.0004
q1.phys_chan.Q_channel_offset = -0.019
q1.phys_chan.amp_factor = 1.004
q1.phys_chan.phase_skew = 0.053
```

```
[ ]: cal = MixerCalibration(q2, specAn, 'control', phase_range = (-0.5, 0.5), amp_range=(0.8,
↳ 1.2))
#cal.calibrate()
```

```
[ ]: q2.phys_chan.I_channel_offset = -0.0004
q2.phys_chan.Q_channel_offset = -0.019
q2.phys_chan.amp_factor = 0.985
q2.phys_chan.phase_skew = 0.074
```

```
[ ]: cal = MixerCalibration(q1, specAn, 'measure', phase_range = (-0.5, 0.5), amp_range=(0.8,
↳ 1.2))
#cal.calibrate()
```

```
[ ]: cal = MixerCalibration(q2, specAn, 'measure', phase_range = (-0.5, 0.5), amp_range=(0.8,
↳ 1.2))
#cal.calibrate()
```

## Rabi Width

```
[ ]: pf = RabiWidth(q1, np.arange(20e-9, 0.602e-6, 10e-9))
exp = QubitExperiment(pf, averages=200)
plot_pulse_files(pf)
#exp.add_qubit_sweep(q1, "control", "frequency", q1src.frequency + np.linspace(-6e6,
↳ 6e6, 61))
exp.run_sweeps()
```

```
[ ]: pf = RabiWidth(q2, np.arange(20e-9, 0.602e-6, 10e-9))
exp = QubitExperiment(pf, averages=200)
plot_pulse_files(pf)
#exp.add_qubit_sweep(q2, "control", "frequency", q2src.frequency + np.linspace(-2e6,
↳ 2e6, 21))
#exp.add_qubit_sweep(q2, "measure", "frequency", AM2.frequency + np.linspace(-2e6,
↳ 2e6, 11))
exp.run_sweeps()
```

## Rabi Amp

```
[ ]: pf = RabiAmp(q1, np.linspace(-1, 1, 101))
exp = QubitExperiment(pf, averages=128)
exp.run_sweeps()
```

```
[ ]: cal = RabiAmpCalibration(q1, quad='imag')
#cal.calibrate()
```

```
[ ]: q1.pulse_params['piAmp'] = 0.6179
q1.pulse_params['pi2Amp'] = q1.pulse_params['piAmp']/2
```

```
[ ]: pf = RabiAmp(q2, np.linspace(-1, 1, 101))
exp = QubitExperiment(pf, averages=128)
exp.run_sweeps()
```

```
[ ]: cal = RabiAmpCalibration(q2,quad='imag')
      #cal.calibrate()
```

```
[ ]: q2.pulse_params['piAmp'] = 0.743
      q2.pulse_params['pi2Amp'] = q2.pulse_params['piAmp']/2
```

## Ramsey Calibration

```
[ ]: # need to be in the neighbourhood for this to work

      cal = RamseyCalibration(q1,quad='imag')
      #cal.calibrate()
```

## T1

```
[ ]: qb = q2
      icpts = np.linspace(20e-9, 201.02e-6, 101)
      pf = InversionRecovery(qb, icpts)
      exp = QubitExperiment(pf, averages=400)
      exp.run_sweeps()
```

```
[ ]: data, desc = exp.writers[0].get_data()
```

```
[ ]: from auspex.analysis.qubit_fits import T1Fit, RamseyFit
      from auspex.analysis.helpers import cal_scale
```

```
[ ]: sdata = cal_scale(data)
```

```
[ ]: fit = T1Fit(icpts, abs(data[0:-4]))
```

```
[ ]: fit.make_plots()
```

## T2

```
[ ]: rpts = np.linspace(20e-9, 50.02e-6, 101)
      pf = Ramsey(q1, rpts ,TPPIFreq=0e3)
      #exp.add_qubit_sweep(q1, "control", "frequency", q1src.frequency + np.linspace(-2e6,
      ↪ 2e6, 21))
      exp = QubitExperiment(pf, averages=200)
      exp.run_sweeps()
```

```
[ ]: data, desc = exp.writers[0].get_data()
      sdata = cal_scale(data)
```

```
[ ]: fit = RamseyFit(rpts, abs(data[0:-4]),make_plots = True)
```



```
[ ]: fcorrect = fit.fit_params['f']

[ ]: fcorrect

[ ]: #q1src.frequency -= fcorrect

[ ]: pf = Ramsey(q2, rpts, TPPIFreq=0e3)
    exp = QubitExperiment(pf, averages=200)
    exp.run_sweeps()

[ ]: data, desc = exp.writers[0].get_data()
    sdata = cal_scale(data)

[ ]: fit = RamseyFit(rpts, abs(data[0:-4]), make_plots = True)
    fcorrect = fit.fit_params['f']

[ ]: fcorrect*1e-6

[ ]: #q2src.frequency += fcorrect
```

### Echo experiments

```
[ ]: exp = QubitExperiment(HahnEcho(q2, np.linspace(20e-9, 80.02e-6, 81), periods=5),
    ↪averages=512)
    exp.run_sweeps()

[ ]: data, desc = exp.writers[0].get_data()
    cdata = cal_scale(np.real(data))
    fit = RamseyFit(desc.axes[0].points[:4], cdata, make_plots=True)
    fit.fit_params
```

### Single Qubit Cals

```
[ ]: RabiAmpCalibration(q1, quad="imag").calibrate()

[ ]: PiCalibration(q1, quad="imag", num_pulses=7).calibrate()

[ ]: Pi2Calibration(q1, quad="imag", num_pulses=7).calibrate()
```

### Single-Qubit RB

```
[ ]: from auspex.analysis.qubit_fits import *
    from auspex.analysis.helpers import *

[ ]: rb_lens = [2, 4, 8, 16, 32, 128, 256, 512]
```

```
[ ]: rb_seqs = create_RB_seqs(1, rb_lens)
    pf = SingleQubitRB(q1, rb_seqs)

[ ]: exp = QubitExperiment(pf, averages=256)
    exp.run_sweeps()

[ ]: data, desc = exp.writers[0].get_data()

[ ]: lens = [int(l) for l in desc.axes[0].points[:-4]]

[ ]: SingleQubitRBfit(lens, cal_scale(np.imag(data)), make_plots=True)
```

## Fancier things

Maybe you want to see how  $T_1$  varies with repeated measurement...

```
[ ]: from auspex.parameter import IntParameter
    import time

[ ]: N = 1000
    lengths = np.linspace(20e-9, 500.02e-6, 101)

[ ]: T1seq = [[X(q2), Id(q2, length=d), MEAS(q2)] for d in lengths]
    T1seq += create_cal_seqs((q2,), 2)

[ ]: wait_param = IntParameter(default=0)
    wait_param.name = "Repeat"
    #wait = lambda x: print(f"{x}")
    def wait(x):
        print(f"{x}")
        time.sleep(2)
    wait_param.assign_method(wait)

    mf = compile_to_hardware(T1seq, "T1/T1")
    exp = QubitExperiment(mf, averages=512)
    exp.wait_param = wait_param
    # with these params each shot is roughly 22 secs apart

    exp.add_sweep(exp.wait_param, list(range(N))) # repeat T1 scan 1000 times
    exp.run_sweeps()

[ ]: # load data
    # get T1s
    T1s = []
    T1_error = []
    #data, desc = exp.writers[0].get_data()
    for i in range(N):
        cdata = cal_scale(np.imag(data[i,:]))
        fit = T1Fit(lengths, cdata, make_plots=False)
        T1s.append(fit.fit_params["T1"])
        T1_error.append(fit.fit_errors["T1"])
```

```
[ ]: plt.figure(figsize=(8,6))
      #plt.errorbar(range(1000),np.array(T1s)*1e6, yerr=np.array(T1_error)*1e6, fmt='+',
      ↪elinewidth=0.5, barsabove=True, capsize=0.7)
      plt.plot(range(1000),np.array(T1s)*1e6, '+')
      plt.title(r'Q2 $T_1$ Variability')
      plt.xlabel('N repeats')
      plt.ylabel(r'$T_1$ (us)')
      #plt.savefig('T1vsTime.png', dpi=300, bbox_inches='tight')
```

## 2Q RB

```
[ ]: lengths = [2,4,6,8,10] # range(2,10) #[2*n for n in range(1,6)]
      seqs = create_RB_seqs(2, lengths=lengths)
      exp = qef.create(TwoQubitRB(q1, q2, seqs=seqs), expname='Q2Q1RB')
      exp.run_sweeps()
```

## 2Q Gates

```
[ ]: edge12 = cl.new_edge(q1,q2)
      cl.set_control(edge12, aps2.tx(5), generator=q1src)
```

```
[ ]: q1_10 = q1.phys_chan.generator.frequency + q1.frequency
      q2_10 = q2.phys_chan.generator.frequency + q2.frequency
```

```
[ ]: edge12.frequency = q2_10 - q1.phys_chan.generator.frequency
```

```
[ ]: edge12.pulse_params = {'length': 400e-9, 'amp': 0.8, 'shape_fun': 'tanh', 'sigma':10e-
      ↪9}
```

```
[ ]: q1.measure_chan.pulse_params['amp'] = 1.0
      q2.measure_chan.pulse_params['amp'] = 1.0
```

## CR length cal

```
[ ]: crlens = np.arange(100e-9,2.1e-6,100e-9)
      pf = EchoCRLen(q1,q2,lengths=crlens)
      plot_pulse_files(pf)
```

```
[ ]: exp = QubitExperiment(pf, averages=512)
      exp.run_sweeps()
```

Above just runs the experiment used by the calibration routine. Here is the actual calibration:

```
[ ]: crlens = np.arange(100e-9,2.1e-6,100e-9)
      # phase, amp and rise_fall have defaults but you can overwrite them
      pce = CRLenCalibration(cl["q1->q2"], lengths=lengths, phase = 0, amp = 0.8, rise_fall_
      ↪= 40e-9,
      do_plotting=True, sample_name="CRLen", averages=512)
      pec.calibrate()
```

## CR phase cal

```
[ ]: phases = np.arange(0, np.pi*2, np.pi/20)
    pf = EchoCRPhase(q1, q2, phases, length=1000e-9)
    plot_pulse_files(pf)

[ ]: exp = QubitExperiment(pf, averages=512)
    exp.run_sweeps()

[ ]: phases = np.linspace(0, 2*np.pi, 21)
    pce = CRPhaseCalibration(edge12, phases = phases, amp = 0.8, rise_fall = 40e-9,
                             do_plotting=True, sample_name="CRPhase", averages=512)
    pec.calibrate()
```

## CR amp cal

```
[ ]: amps = np.arange(0.7, 0.9, 0.1)
    pf = EchoCRAmp(q1, q2, amps, length=1000e-9)
    plot_pulse_files(pf)

[ ]: exp = QubitExperiment(pf, averages=512)
    exp.run_sweeps()

[ ]: pce = CRAmpCalibration(cl["q1->q2"], amp_range = 0.2, rise_fall = 40e-9,
                             do_plotting=True, sample_name="CRAmp", averages=512)
    pec.calibrate()
```

## 3.4.3 Instrument Drivers

For `libaps2`, `libalazar`, and `libx6`, one should be able to `conda install -c bbn-q xxx` in order to obtain binary distributions of the relevant packages. Otherwise, one must obtain and build those libraries (according to their respective documentation), then make the shared library build products and any python packages available to Auspex by placing them on the path.

## 3.5 Plot Server

Auspex plotting is facilitated by a plot server and plot clients. A single server can handle multiple running experiments, which publish their data with a unique UUID. Many clients can connect to the server and request data for a particular UUID.

### 3.5.1 Running the Plot Server

The plot server must currently be started manually with:

```
python plot_server.py
```

### 3.5.2 Running the Plot Client

The plot client *matplotlib-client.py* should be run automatically whenever plotters are put in an experiment's filter pipeline. The code can be run manually and used to connect to a remote system, simply by running the executable with:

```
python matplotlib-client.py
```

## 3.6 auspex package

### 3.6.1 Subpackages

**auspex.analysis package**

**Submodules**

**auspex.analysis.fits module**

**class** `auspex.analysis.fits.Auspex2DFit` (*xpts, ypts, zpts, make\_plots=False*)

A generic fit class wrapping `scipy.optimize.curve_fit` for convenience. Specific fits should inherit this class.

**xlabel**

Plot x-axis label.

**Type** str

**ylabel**

Plot y-axis label.

**Type** str

**title**

Plot title.

**Type** str

**annotation()**

Annotation for the *make\_plot()* method. Should return a string that is passed to *matplotlib.pyplot.annotate*.

**make\_plots()**

Create a plot of the input data and the fitted model. By default will include any annotation defined in the *annotation()* class method.

**model** (*x=None*)

The fit function evaluated at the parameters found by *curve\_fit*.

**Parameters** **x** – A number or *numpy.array* returned by the model function.

**title** = 'Auspex Fit'

**xlabel** = 'X points'

**ylabel** = 'Y points'

**class** `auspex.analysis.fits.AuspexFit` (*xpts, ypts, make\_plots=False, ax=None*)

A generic fit class wrapping `scipy.optimize.curve_fit` for convenience. Specific fits should inherit this class.

```

xlabel
    Plot x-axis label.

    Type str

ylabel
    Plot y-axis label.

    Type str

title
    Plot title.

    Type str

annotation()
    Annotation for the make_plot() method. Should return a string that is passed to matplotlib.pyplot.annotate.

ax = None

bounds = None

make_plots()
    Create a plot of the input data and the fitted model. By default will include any annotation defined in the
    annotation() class method.

model (x=None)
    The fit function evaluated at the parameters found by curve_fit.

    Parameters x – A number or numpy.array returned by the model function.

title = 'Auspex Fit'
xlabel = 'X points'
ylabel = 'Y points'

class auspex.analysis.fits.GaussianFit (xpts, ypts, make_plots=False, ax=None)
    A fit to a gaussian function

    title = 'Gaussian Fit'
xlabel = 'X Data'
ylabel = 'Y Data'

class auspex.analysis.fits.LorentzFit (xpts, ypts, make_plots=False, ax=None)
    A fit to a simple Lorentzian function  $A / ((x-b)^2 + (c/2)^2) + d$ 

    title = 'Lorentzian Fit'
xlabel = 'X Data'
ylabel = 'Y Data'

class auspex.analysis.fits.MultiGaussianFit (x, y, make_plots=False, n_gaussians=2, n_samples=100000)
    A fit to a sum of gaussian function. Use with care!

    title = 'Sum of Gaussians Fit'
xlabel = 'X Data'
ylabel = 'Y Data'

class auspex.analysis.fits.QuadraticFit (xpts, ypts, make_plots=False, ax=None)
    A fit to a simple quadratic function  $A*(x-x_0)**2 + b$ 
    
```

```

title = 'Quadratic Fit'
xlabel = 'X Data'
ylabel = 'Y Data'

```

## auspex.analysis.helpers module

`auspex.analysis.helpers.cal_data` (*data*, *quad*=<function *real*>, *qubit\_name*='q1', *group\_name*='main', *return\_type*=<class 'numpy.float32'>, *key*=")

Rescale data to  $\sigma_z$  expectation value based on calibration sequences.

### Parameters

- **data** (*numpy array*) – The data from the writer or buffer, which is a dictionary whose keys are typically in the format qubit\_name-group\_name, e.g. ({'q1-main'} : array([(0.0+0.0j, ...), (...), ...]))
- **quad** (*numpy function*) – This should be the quadrature where most of the data can be found. Options are: np.real, np.imag, np.abs and np.angle
- **qubit\_name** (*string*) – Name of the qubit in the data file. Default is 'q1'
- **group\_name** (*string*) – Name of the data group to calibrate. Default is 'main'
- **return\_type** (*numpy data type*) – Type of the returned data. Default is np.float32.
- **key** (*string*) – In the case where the dictionary keys don't conform to the default format a string can be passed in specifying the data key to scale.

### Returns

**numpy array (type return\_type)** Returns the data rescaled to match the calibration results for the  $\sigma_z$  expectation value.

## Examples

Loading and calibrating data

```

>>> exp = QubitExperiment(T1(q1), averages=500)
>>> exp.run_sweeps()
>>> data, desc = exp.writers[0].get_data()

```

`auspex.analysis.helpers.cal_ls()`

List of auspex.pulse\_calibration results

`auspex.analysis.helpers.cal_scale` (*data*, *bit*=0, *nqubits*=1, *repeats*=2)

Scale data from calibration points. :param data: :type data: Unscaled data with cal points. :param bit: :type bit: Which qubit in the sequence is to be calibrated (0 for 1st, etc...). Default 0. :param nqubits: :type nqubits: Number of qubits in the data. Default 1. :param repeats: :type repeats: Number of calibration repeats. Default 2.

### Returns data

**Return type** scaled data array

`auspex.analysis.helpers.get_cals` (*qubit*, *params*, *make\_plots*=True, *depth*=0)

Return and optionally plot the result of the most recent calibrations/characterizations :param qubit: :type qubit: qubit name (string) :param params: :type params: parameter(s) to plot (string or list of strings) :param

make\_plots: :type make\_plots: optional bool (default = True) :param depth: :type depth: optional integer, number of most recent calibrations to load (default = 0 for all cal) :param \_\_\_\_\_: :param Returns: :param List of: :type List of: dates, values, errors

`auspex.analysis.helpers.get_file_name()`

Helper function to get a filepath from a dialog box

`auspex.analysis.helpers.load_data(dirpath=None)`

Open data in the .auspex file at dirpath/

**Parameters** `dirpath` (*string*) – Path to the .auspex file. If no folder is specified, a dialogue box will ask for a path.

**Returns**

`data_set` (`Dict{data group}{data name}{data,descriptor}`) Data as a dictionary structure with data groups, types of data and the data packed sequentially

## Examples

Loading a data container

```
>>> data = load_data('/path/to/my/data.auspex')
>>> data
{'q2-main': {'data': {'data': array([[ 0.16928101-0.05661011j,  0.3225708 +0.
↪08914185j,
      0.2114563 +0.10314941j, ..., -0.32357788+0.16964722j,
>>> data["q3-main"]["variance"]["descriptor"]
<DataStreamDescriptor(num_dims=1, num_points=52)>
>>> data["q3-main"]["variance"]["data"]
array([0.000944496+0.00014886j, 0.00089747+0.00015082j,
      0.00090634+0.00015106j, 0.00090128+0.00014451j,...
```

`auspex.analysis.helpers.normalize_buffer_data(data, desc, qubit_index, zero_id=0, one_id=1)`

`auspex.analysis.helpers.normalize_data(data, zero_id=0, one_id=1)`

`auspex.analysis.helpers.open_data(num=None, folder=None, groupname='main', datasetname='data', date=None)`

**Convenience Load data from an *AuspexDataContainer* given a file number and folder.** Assumes that files are named with the convention *ExperimentName-NNNNN.auspex*

**Parameters**

- **num** (*int*) – File number to be loaded.
- **folder** (*string*) – Base folder where file is stored. If the *date* parameter is not None, assumes file is a dated folder. If no folder is specified, open a dialogue box. Open the folder with the desired ExperimentName-NNNN.auspex, then press OK
- **groupname** (*string*) – Group name of data to be loaded.
- **datasetname** (*string, optional*) – Data set name to be loaded. Default is “data”.
- **date** (*string, optional*) – Date folder from which data is to be loaded. Format is “YYMMDD” Defaults to today’s date.

**Returns**

`data` (`numpy.array`) Data loaded from file.



**desc (DataSetDescriptor)** Dataset descriptor loaded from file.

## Examples

Loading a data container

```
>>> data, desc = open_data(42, '/path/to/my/data', "q1-main", date="190301")
```

## Module contents

### auspex.filters package

#### Submodules

#### auspex.filters.average module

#### auspex.filters.channelizer module

```
class auspex.filters.channelizer.Channelizer(frequency=None, bandwidth=None, dec-
                                             imation_factor=None, follow_axis=None,
                                             follow_freq_offset=None, **kwargs)
```

Digital demodulation and filtering to select a particular frequency multiplexed channel. If an axis name is supplied to *follow\_axis* then the filter will demodulate at the frequency *axis\_frequency\_value* - *follow\_freq\_offset* otherwise it will demodulate at *frequency*. Note that the filter coefficients are still calculated with respect to the *frequency* paramter, so it should be chosen accordingly when *follow\_axis* is defined.

```
bandwidth = <FloatParameter(name='bandwidth',value=5000000.0)>
```

```
decimation_factor = <IntParameter(name='decimation_factor',value=4)>
```

```
final_init()
```

```
follow_axis = <Parameter(name='follow_axis',value='')>
```

```
follow_freq_offset = <FloatParameter(name='follow_freq_offset',value=0.0)>
```

```
frequency = <FloatParameter(name='frequency',value=10000000.0)>
```

```
init_filters(frequency, bandwidth)
```

```
process_data(data)
```

```
sink = <InputConnector(name=)>
```

```
source = <OutputConnector(name=)>
```

```
update_descriptors()
```

This method is called whenever the connectivity of the graph changes. This may have implications for the internal functioning of the filter, in which case `update_descriptors` should be overloaded. Any simple changes to the axes within the `StreamDescriptors` should take place via the class method `descriptor_map`.

```
update_references(frequency)
```

## auspex.filters.correlator module

```
class auspex.filters.correlator.Correlator (filter_name=None, **kwargs)

    filter_name = 'Correlator'
    operation ()
        Must be overridden with the desired mathematical function
    sink = <InputConnector (name=)>
    source = <OutputConnector (name=)>
    unit (base_unit)
        Must be overridden according the desired mathematical function e.g.  return base_unit + “^{}”.format(len(self.sink.input_streams))
```

## auspex.filters.debug module

```
class auspex.filters.debug.Print (*args, **kwargs)
    Debug printer that prints data coming through filter

    process_data (data)
    sink = <InputConnector (name=)>

class auspex.filters.debug.Passthrough (*args, **kwargs)

    process_data (data)
    sink = <InputConnector (name=)>
    source = <OutputConnector (name=)>
```

## auspex.filters.elementwise module

```
class auspex.filters.elementwise.ElementwiseFilter (filter_name=None, **kwargs)
    Perform elementwise operations on multiple streams: e.g. multiply or add all streams element-by-element

    filter_name = 'GenericElementwise'
    main ()
        Generic run method which waits on a single stream and calls process_data on any new_data
    operation ()
        Must be overridden with the desired mathematical function
    sink = <InputConnector (name=)>
    source = <OutputConnector (name=)>
    unit (base_unit)
        Must be overridden according the desired mathematical function e.g.  return base_unit + “^{}”.format(len(self.sink.input_streams))
    update_descriptors ()
        Must be overridden depending on the desired mathematical function
```

### auspex.filters.filter module

```
class auspex.filters.filter.Filter (name=None, **kwargs)
    Any node on the graph that takes input streams with optional output streams

    checkin ()
        For any filter-specific loop needs

    configure_with_proxy (proxy_obj)
        For use with bbndb, sets this filter's properties using a FilterProxy object taken from the filter database.

    descriptor_map (input_descriptors)
        Return a dict of the output descriptors.

    execute_on_run ()

    main ()
        Generic run method which waits on a single stream and calls process_data on any new_data

    on_done ()
        To be run when the done signal is received, in case additional steps are needed (such as flushing a plot or
        data).

    process_message (msg)
        To be overridden for interesting default behavior

    push_resource_usage ()

    push_to_all (message)

    run ()
        Method to be run in sub-process; can be overridden in sub-class

    shutdown ()

    update_descriptors ()
        This method is called whenever the connectivity of the graph changes. This may have implications for
        the internal functioning of the filter, in which case update_descriptors should be overloaded. Any simple
        changes to the axes within the StreamDescriptors should take place via the class method descriptor_map.
```

### auspex.filters.framer module

```
class auspex.filters.framer.Framer (axis=None, **kwargs)
    Mete out data in increments defined by the specified axis.

    axis = <Parameter (name='axis', value=None)>

    final_init ()

    process_data (data)

    sink = <InputConnector (name=)>

    source = <OutputConnector (name=)>
```

### auspex.filters.integrator module

```
class auspex.filters.integrator.KernelIntegrator (**kwargs)

    bias = <FloatParameter (name='bias', value=0.0)>
```

```

box_car_start = <FloatParameter(name='box_car_start',value=0.0)>
box_car_stop = <FloatParameter(name='box_car_stop',value=1e-07)>
demod_frequency = <FloatParameter(name='demod_frequency',value=0.0)>
    Integrate with a given kernel. Kernel will be padded/truncated to match record length
kernel = <Parameter(name='kernel',value=None)>
process_data(data)
simple_kernel = <BoolParameter(name='simple_kernel',value=True)>
sink = <InputConnector(name=)>
source = <OutputConnector(name=)>
update_descriptors()

```

This method is called whenever the connectivity of the graph changes. This may have implications for the internal functioning of the filter, in which case `update_descriptors` should be overloaded. Any simple changes to the axes within the `StreamDescriptors` should take place via the class method `descriptor_map`.

### auspex.filters.io module

```

class auspex.filters.io.WriteToFile(filename=None, groupname=None, datasetname=None,
                                     **kwargs)
    Writes data to file using the Auspex container type, which is a simple directory structure with subdirectories,
    binary datafiles, and json meta files that store the axis descriptors and other information.

    datasetname = <Parameter(name='datasetname',value='data')>
    filename = <Parameter(name='filename',value=None)>
    final_init()
    get_data()
    get_data_while_running(return_queue)
        Return data to the main thread or user as requested. Use a MP queue to transmit.
    groupname = <Parameter(name='groupname',value='main')>
    process_data(data)
    sink = <InputConnector(name=)>

class auspex.filters.io.DataBuffer(**kwargs)
    Writes data to IO.

    checkin()
        For any filter-specific loop needs
    final_init()
    get_data()
    main()
        Generic run method which waits on a single stream and calls process_data on any new_data
    process_data(data)
    sink = <InputConnector(name=)>

```

**auspex.filters.plot module**

```

class auspex.filters.plot.Plotter(*args, name="", plot_dims=None, plot_mode=None,
                                   **plot_args)

    axis_label(index)
    desc()
    execute_on_run()
    final_init()
    get_final_plot(quad_funcs=[<ufunc 'absolute'>, <function angle>])
    on_done()
        To be run when the done signal is received, in case additional steps are needed (such as flushing a plot or
        data).
    plot_dims = <IntParameter(name='plot_dims',value=0)>
    plot_mode = <Parameter(name='plot_mode',value='quad')>
    process_data(data)
    send(message)
    set_done()
    set_quit()
    sink = <InputConnector(name=)>
    update()
    update_descriptors()
        This method is called whenever the connectivity of the graph changes. This may have implications for
        the internal functioning of the filter, in which case update_descriptors should be overloaded. Any simple
        changes to the axes within the StreamDescriptors should take place via the class method descriptor_map.

class auspex.filters.plot.ManualPlotter(name="", x_label=['X'], y_label=['y'],
                                          y_lim=None, numplots=1)
    Establish a figure, then give the user complete control over plot creation and data. There isn't any reason to run
    this as a process, but we provide the same interface for convenience.

    add_data_trace(name, custom_mpl_kwargs={}, subplot_num=0)
    add_fit_trace(name, custom_mpl_kwargs={}, subplot_num=0)
    add_trace(name, matplotlib_kwargs={}, subplot_num=0)
    desc()
    execute_on_run()
    send(message)
    set_data(trace_name, xdata, ydata)
    set_done()
    set_quit()
    start()
    stop()

```

```
class auspex.filters.plot.MeshPlotter(*args, name="", plot_mode=None, x_label="",
                                     y_label="", **plot_args)

    desc()

    execute_on_run()

    on_done()
        To be run when the done signal is received, in case additional steps are needed (such as flushing a plot or
        data).

    plot_mode = <Parameter(name='plot_mode', value='quad')>
    process_direct(data)
    send(message)
    sink = <InputConnector(name=)>
    update_descriptors()
        This method is called whenever the connectivity of the graph changes. This may have implications for
        the internal functioning of the filter, in which case update_descriptors should be overloaded. Any simple
        changes to the axes within the StreamDescriptors should take place via the class method descriptor_map.
```

SingleShotMeasurement auspex.filters.singleshot module —————

```
class auspex.filters.singleshot.SingleShotMeasurement(save_kernel=False,    opti-
                                                    mal_integration_time=False,
                                                    zero_mean=False,
                                                    set_threshold=False,    lo-
                                                    gistic_regression=False,
                                                    **kwargs)

    TOLERANCE = 0.001

    compute_filter()
        Compute the single shot kernel and obtain single-shot measurement fidelity.

        Expects that the data will be in self.ground_data and self.excited_data, which are (T, N)-shaped numpy
        arrays, with T the time axis and N the number of shots.

    final_init()

    logistic_fidelity()

    logistic_regression = <BoolParameter(name='logistic_regression', value=False)>
    optimal_integration_time = <BoolParameter(name='optimal_integration_time', value=False)>
    process_data(data)
        Fill the ground and excited data bins

    save_kernel = <BoolParameter(name='save_kernel', value=False)>
    set_threshold = <BoolParameter(name='set_threshold', value=False)>
    sink = <InputConnector(name=)>
    source = <OutputConnector(name=)>
    update_descriptors()
        This method is called whenever the connectivity of the graph changes. This may have implications for
        the internal functioning of the filter, in which case update_descriptors should be overloaded. Any simple
        changes to the axes within the StreamDescriptors should take place via the class method descriptor_map.
```

```
zero_mean = <BoolParameter(name='zero_mean',value=False)>
```

## auspex.filters.stream\_selectors module

### Module contents

## auspex.instruments package

### Submodules

## auspex.instruments.agilent module

```
class auspex.instruments.agilent.Agilent33220A(resource_name=None,           *args,
                                              **kwargs)
    Agilent 33220A Function Generator
    FUNCTION_MAP = {'DC': 'DC', 'Noise': 'NOIS', 'Pulse': 'PULS', 'Ramp': 'RAMP', 'Sine':
    amplitude
    auto_range
    burst_cycles
    burst_mode
    burst_state
    connect (resource_name=None, interface_type=None)
        Either connect to the resource name specified during initialization, or specify a new resource name here.
    dc_offset
    frequency
    function
    get_amplitude (**kwargs)
    get_auto_range (**kwargs)
    get_burst_cycles (**kwargs)
    get_burst_mode (**kwargs)
    get_burst_state (**kwargs)
    get_dc_offset (**kwargs)
    get_frequency (**kwargs)
    get_function (**kwargs)
    get_high_voltage (**kwargs)
    get_load_resistance (**kwargs)
    get_low_voltage (**kwargs)
    get_output (**kwargs)
    get_output_sync (**kwargs)
    get_output_units (**kwargs)
```

```
get_polarity (**kwargs)
get_pulse_dcyc (**kwargs)
get_pulse_edge (**kwargs)
get_pulse_period (**kwargs)
get_pulse_width (**kwargs)
get_ramp_symmetry (**kwargs)
get_trigger_slope (**kwargs)
get_trigger_source (**kwargs)
high_voltage
load_resistance
low_voltage
output
output_sync
output_units
polarity
pulse_dcyc
pulse_edge
pulse_period
pulse_width
ramp_symmetry
set_amplitude (val, **kwargs)
set_auto_range (val, **kwargs)
set_burst_cycles (val, **kwargs)
set_burst_mode (val, **kwargs)
set_burst_state (val, **kwargs)
set_dc_offset (val, **kwargs)
set_frequency (val, **kwargs)
set_function (val, **kwargs)
set_high_voltage (val, **kwargs)
set_load_resistance (val, **kwargs)
set_low_voltage (val, **kwargs)
set_output (val, **kwargs)
set_output_sync (val, **kwargs)
set_output_units (val, **kwargs)
set_polarity (val, **kwargs)
set_pulse_dcyc (val, **kwargs)
```



```

    set_pulse_edge (val, **kwargs)
    set_pulse_period (val, **kwargs)
    set_pulse_width (val, **kwargs)
    set_ramp_symmetry (val, **kwargs)
    set_trigger_slope (val, **kwargs)
    set_trigger_source (val, **kwargs)
    trigger ()
    trigger_slope
    trigger_source

class auspex.instruments.agilent.Agilent33500B (resource_name=None, *args,
                                                **kwargs)
    Agilent/Keysight 33500 series 2-channel Arbitrary Waveform Generator
    Replacement model for 33220 series with some changes and additional sequencing functionality
    FUNCTION_MAP = {'DC': 'DC', 'Noise': 'NOIS', 'PRBS': 'PRBS', 'Pulse': 'PULS', 'Ramp':
class Segment (name, data=[], dac=True, control='once', repeat=0, mkr_mode='maintain',
                mkr_pts=4)

    self_check ()
    update (**kwargs)

class Sequence (name)

    add_segment (segment, **kwargs)
        Create a copy of the segment, update its values, then add to the sequence. The copy and update are
        to allow reuse of the same segment with different configurations. For safety, avoid reuse, but add
        different segment objects to the sequence.

    get_descriptor ()
        Return block descriptor to upload to the instrument

abort ()

amplitude = <auspex.instruments.instrument.FloatCommand object>
arb_advance = <auspex.instruments.instrument.StringCommand object>
arb_amplitude = <auspex.instruments.instrument.FloatCommand object>
arb_frequency = <auspex.instruments.instrument.FloatCommand object>
arb_sample = <auspex.instruments.instrument.FloatCommand object>
arb_sync ()
    Restart the sequences and synchronize them

arb_waveform = <auspex.instruments.instrument.StringCommand object>
auto_range = <auspex.instruments.instrument.Command object>
burst_cycles = <auspex.instruments.instrument.FloatCommand object>
burst_mode = <auspex.instruments.instrument.StringCommand object>
burst_state = <auspex.instruments.instrument.Command object>

```

**clear\_waveform** (*channel=1*)

Clear all waveforms loaded in the memory

**connect** (*resource\_name=None, interface\_type=None*)

Either connect to the resource name specified during initialization, or specify a new resource name here.

**dc\_offset** = <auspex.instruments.instrument.FloatCommand object>

**frequency** = <auspex.instruments.instrument.FloatCommand object>

**function** = <auspex.instruments.instrument.StringCommand object>

**get\_amplitude** (*\*\*kwargs*)

**get\_arb\_advance** (*\*\*kwargs*)

Advance mode to the next point: 'Trigger' or 'Srate' (Sample Rate)

**get\_arb\_amplitude** (*\*\*kwargs*)

**get\_arb\_frequency** (*\*\*kwargs*)

**get\_arb\_sample** (*\*\*kwargs*)

Sample Rate

**get\_arb\_waveform** (*\*\*kwargs*)

**get\_auto\_range** (*\*\*kwargs*)

**get\_burst\_cycles** (*\*\*kwargs*)

**get\_burst\_mode** (*\*\*kwargs*)

**get\_burst\_state** (*\*\*kwargs*)

**get\_dc\_offset** (*\*\*kwargs*)

**get\_frequency** (*\*\*kwargs*)

**get\_function** (*\*\*kwargs*)

**get\_high\_voltage** (*\*\*kwargs*)

**get\_load** (*\*\*kwargs*)

Expected load resistance, 1-10k

**get\_low\_voltage** (*\*\*kwargs*)

**get\_output** (*\*\*kwargs*)

**get\_output\_gated** (*\*\*kwargs*)

**get\_output\_sync** (*\*\*kwargs*)

**get\_output\_trigger** (*\*\*kwargs*)

**get\_output\_trigger\_slope** (*\*\*kwargs*)

**get\_output\_trigger\_source** (*\*\*kwargs*)

**get\_output\_units** (*\*\*kwargs*)

**get\_polarity** (*\*\*kwargs*)

**get\_pulse\_dcyc** (*\*\*kwargs*)

**get\_pulse\_edge** (*\*\*kwargs*)

**get\_pulse\_period** (*\*\*kwargs*)

**get\_pulse\_width** (*\*\*kwargs*)

```

get_ramp_symmetry (**kwargs)
get_sequence (**kwargs)
get_sync_mode (**kwargs)
get_sync_polarity (**kwargs)
get_sync_source (**kwargs)
get_trigger_slope (**kwargs)
get_trigger_source (**kwargs)
high_voltage = <auspex.instruments.instrument.FloatCommand object>
load = <auspex.instruments.instrument.FloatCommand object>
low_voltage = <auspex.instruments.instrument.FloatCommand object>
output = <auspex.instruments.instrument.Command object>
output_gated = <auspex.instruments.instrument.Command object>
output_sync = <auspex.instruments.instrument.Command object>
output_trigger
output_trigger_slope
output_trigger_source
output_units = <auspex.instruments.instrument.Command object>
polarity = <auspex.instruments.instrument.Command object>
pulse_dcyc = <auspex.instruments.instrument.IntCommand object>
pulse_edge = <auspex.instruments.instrument.FloatCommand object>
pulse_period = <auspex.instruments.instrument.FloatCommand object>
pulse_width = <auspex.instruments.instrument.FloatCommand object>
ramp_symmetry
sequence = <auspex.instruments.instrument.StringCommand object>
set_amplitude (val, **kwargs)
set_arb_advance (val, **kwargs)
    Advance mode to the next point: 'Trigger' or 'Srate' (Sample Rate)
set_arb_amplitude (val, **kwargs)
set_arb_frequency (val, **kwargs)
set_arb_sample (val, **kwargs)
    Sample Rate
set_arb_waveform (val, **kwargs)
set_auto_range (val, **kwargs)
set_burst_cycles (val, **kwargs)
set_burst_mode (val, **kwargs)
set_burst_state (val, **kwargs)
set_dc_offset (val, **kwargs)

```

```

set_frequency (val, **kwargs)
set_function (val, **kwargs)
set_high_voltage (val, **kwargs)
set_infinite_load (channel=1)
set_load (val, **kwargs)
    Expected load resistance, 1-10k
set_low_voltage (val, **kwargs)
set_output (val, **kwargs)
set_output_gated (val, **kwargs)
set_output_sync (val, **kwargs)
set_output_trigger (val, **kwargs)
set_output_trigger_slope (val, **kwargs)
set_output_trigger_source (val, **kwargs)
set_output_units (val, **kwargs)
set_polarity (val, **kwargs)
set_pulse_dcyc (val, **kwargs)
set_pulse_edge (val, **kwargs)
set_pulse_period (val, **kwargs)
set_pulse_width (val, **kwargs)
set_ramp_symmetry (val, **kwargs)
set_sequence (val, **kwargs)
set_sync_mode (val, **kwargs)
set_sync_polarity (val, **kwargs)
set_sync_source (val, **kwargs)
set_trigger_slope (val, **kwargs)
set_trigger_source (val, **kwargs)

sync_mode = <auspex.instruments.instrument.StringCommand object>
sync_polarity = <auspex.instruments.instrument.Command object>
sync_source
trigger (channel=1)
trigger_slope
trigger_source
upload_sequence (sequence, channel=1, binary=False)
    Upload a sequence to the instrument
upload_waveform (data, channel=1, name='mywaveform', dac=True)
    Load string-converted data into a waveform memory
    dac: True if values are converted to integer already
    
```

```
upload_waveform_binary (data, channel=1, name='mywaveform', dac=True)
    NOT YET WORKING - DO NOT USE Load binary data into a waveform memory
```

dac: True if values are converted to integer already

```
class auspex.instruments.agilent.Agilent34970A (resource_name=None, *args, **kwargs)

    Agilent 34970A MUX

    ADVSOUR_VALUES = ['EXT', 'BUS', 'IMM']
    CONFIG_LIST = []
    ONOFF_VALUES = ['ON', 'OFF']
    PLC_VALUES = [0.02, 0.2, 1, 10, 20, 100, 200]
    RES_VALUES = ['AUTO', 100.0, 1000.0, 10000.0, 100000.0, 1000000.0, 10000000.0, 100000000.0]
    TRIGSOUR_VALUES = ['BUS', 'IMM', 'EXT', 'TIM']

    advance_source
    ch_to_str (ch_list)
    channel_delay
    configlist
    connect (resource_name=None, interface_type=None)
        Either connect to the resource name specified during initialization, or specify a new resource name here.

    dmm
    get_advance_source (**kwargs)
    get_dmm (**kwargs)
    get_trigger_count (**kwargs)
    get_trigger_source (**kwargs)
    get_trigger_timer (**kwargs)
    r_lists ()
    read ()
    resistance_range
    resistance_resolution
    resistance_wire
    resistance_zcomp
    scan ()
    scanlist
    set_advance_source (val, **kwargs)
    set_dmm (val, **kwargs)
    set_trigger_count (val, **kwargs)
    set_trigger_source (val, **kwargs)
    set_trigger_timer (val, **kwargs)
    trigger_count
```

```

    trigger_source
    trigger_timer
class auspex.instruments.agilent.AgilentE8363C (resource_name=None,      *args,
                                              **kwargs)
    Agilent E8363C 2-port 40GHz VNA.
    data_query_raw = False
    ports = (1, 2)
class auspex.instruments.agilent.AgilentN5183A (resource_name=None,      *args,
                                              **kwargs)
    AgilentN5183A microwave source
    alc
    connect (resource_name=None, interface_type='VISA')
        Either connect to the resource name specified during initialization, or specify a new resource name here.
    frequency
    get_alc (**kwargs)
    get_frequency (**kwargs)
    get_mod (**kwargs)
    get_output (**kwargs)
    get_phase (**kwargs)
    get_power (**kwargs)
    instrument_type = 'Microwave Source'
    mod
    output
    phase
    power
    reference
    set_alc (val, **kwargs)
    set_all (settings)
    set_frequency (val, **kwargs)
    set_mod (val, **kwargs)
    set_output (val, **kwargs)
    set_phase (val, **kwargs)
    set_power (val, **kwargs)
class auspex.instruments.agilent.AgilentN9010A (resource_name=None,      *args,
                                              **kwargs)
    Agilent N9010A SA
    averaging_count
    clear_averaging ()

```

**connect** (*resource\_name=None, interface\_type=None*)

Either connect to the resource name specified during initialization, or specify a new resource name here.

**frequency\_center**

**frequency\_span**

**frequency\_start**

**frequency\_stop**

**get\_averaging\_count** (*\*\*kwargs*)

**get\_axis** ()

**get\_frequency\_center** (*\*\*kwargs*)

**get\_frequency\_span** (*\*\*kwargs*)

**get\_frequency\_start** (*\*\*kwargs*)

**get\_frequency\_stop** (*\*\*kwargs*)

**get\_marker1\_amplitude** (*\*\*kwargs*)

**get\_marker1\_position** (*\*\*kwargs*)

**get\_mode** (*\*\*kwargs*)

**get\_num\_sweep\_points** (*\*\*kwargs*)

**get\_pn\_carrier\_freq** (*\*\*kwargs*)

**get\_pn\_offset\_start** (*\*\*kwargs*)

**get\_pn\_offset\_stop** (*\*\*kwargs*)

**get\_pn\_trace** (*num=3*)

**get\_resolution\_bandwidth** (*\*\*kwargs*)

**get\_sweep\_time** (*\*\*kwargs*)

**get\_trace** (*num=1*)

**get\_video\_auto** (*\*\*kwargs*)

**get\_video\_bandwidth** (*\*\*kwargs*)

**instrument\_type** = 'Spectrum Analyzer'

**marker1\_amplitude**

**marker1\_position**

**marker\_X**

Queries marker X-value.

**Parameters** **marker** (*int*) – Marker index (1-12).

**Returns** X axis value of selected marker.

**marker\_Y**

Queries marker Y-value.

**Parameters** **marker** (*int*) – Marker index (1-12).

**Returns** Trace value at selected marker.

**marker\_to\_center** (*marker=1*)

**mode**

**noise\_marker** (*marker=1, enable=True*)

Set/unset marker as a noise marker for noise figure measurements.

**Parameters**

- **marker** (*int*) – Index of marker, [1,12].
- **enable** (*bool*) – Toggles between noise marker (True) and regular marker (False).

**Returns** None.

**num\_sweep\_points**

**peak\_search** (*marker=1*)

**pn\_carrier\_freq**

**pn\_offset\_start**

**pn\_offset\_stop**

**resolution\_bandwidth**

**restart\_sweep** ()

Aborts current sweep and restarts.

**set\_averaging\_count** (*val, \*\*kwargs*)

**set\_frequency\_center** (*val, \*\*kwargs*)

**set\_frequency\_span** (*val, \*\*kwargs*)

**set\_frequency\_start** (*val, \*\*kwargs*)

**set\_frequency\_stop** (*val, \*\*kwargs*)

**set\_marker1\_amplitude** (*val, \*\*kwargs*)

**set\_marker1\_position** (*val, \*\*kwargs*)

**set\_mode** (*val, \*\*kwargs*)

**set\_num\_sweep\_points** (*val, \*\*kwargs*)

**set\_pn\_carrier\_freq** (*val, \*\*kwargs*)

**set\_pn\_offset\_start** (*val, \*\*kwargs*)

**set\_pn\_offset\_stop** (*val, \*\*kwargs*)

**set\_resolution\_bandwidth** (*val, \*\*kwargs*)

**set\_sweep\_time** (*val, \*\*kwargs*)

**set\_video\_auto** (*val, \*\*kwargs*)

**set\_video\_bandwidth** (*val, \*\*kwargs*)

**sweep\_time**

**video\_auto**

**video\_bandwidth**

**class** auspex.instruments.agilent.**HP33120A** (*resource\_name=None, \*args, \*\*kwargs*)

HP33120A Arb Waveform Generator

**amplitude**



```

arb_function (name)
burst_cycles
burst_source
burst_state
connect (resource_name=None, interface_type=None)
    Either connect to the resource name specified during initialization, or specify a new resource name here.
delete_waveform (name='all')
duty_cycle
frequency
function
get_amplitude (**kwargs)
get_burst_cycles (**kwargs)
get_burst_source (**kwargs)
get_burst_state (**kwargs)
get_duty_cycle (**kwargs)
get_frequency (**kwargs)
get_function (**kwargs)
get_load (**kwargs)
get_offset (**kwargs)
get_voltage_unit (**kwargs)
load
offset
set_amplitude (val, **kwargs)
set_burst_cycles (val, **kwargs)
set_burst_source (val, **kwargs)
set_burst_state (val, **kwargs)
set_duty_cycle (val, **kwargs)
set_frequency (val, **kwargs)
set_function (val, **kwargs)
set_load (val, **kwargs)
set_offset (val, **kwargs)
set_voltage_unit (val, **kwargs)
upload_waveform (data, name='volatile')
voltage_unit

```

**class** auspex.instruments.agilent.**AgilentN5230A** (*resource\_name=None, \*args, \*\*kwargs*)

Agilent N5230A 4-port 20GHz VNA.

```
data_query_raw = False
ports = (1, 2, 3, 4)
```

### auspex.instruments.alazar module

```
class auspex.instruments.alazar.AlazarATS9870(resource_name=None, name='Unlabeled
                                              Alazar', gen_fake_data=False)
    Alazar ATS9870 digitizer
    acquire()
    add_channel(channel)
    configure_with_dict(settings_dict)
        Accept a sdict settings dictionary and attempt to set all of the instrument parameters using the key/value pairs.
    connect(resource_name=None)
    data_available()
    disconnect()
    done()
    get_buffer_for_channel(channel)
    get_socket(channel)
    instrument_type = 'Digitizer'
    receive_data(channel, oc, exit, ready, run)
    spew_fake_data(counter, ideal_data, random_mag=0.1, random_seed=12345)
        Generate fake data on the stream. For unittest usage. ideal_data: array or list giving means of the expected
        signal for each segment

        Returns the total number of fake data points, so that we can keep track of how many we expect to receive,
        when we're doing the test with fake data
    stop()
    wait_for_acquisition(dig_run, timeout=5, ocs=None, progressbars=None)
class auspex.instruments.alazar.AlazarChannel(receiver_channel=None)

    phys_channel = None
    set_all(settings_dict)
    set_by_receiver(receiver)
```

### auspex.instruments.ami module

```
class auspex.instruments.ami.AMI430(resource_name, *args, **kwargs)
    AMI430 Power Supply Programmer
    RAMPING_STATES = ['RAMPING to target field/current', 'HOLDING at the target field/current']
    SUPPLY_TYPES = ['AMI 12100PS', 'AMI 12200PS', 'AMI 4Q05100PS', 'AMI 4Q06125PS', 'AMI 4Q06125PS', 'AMI 4Q06125PS']
    absorber
```

**coil\_const**

**connect** (*resource\_name=None, interface\_type=None*)

Either connect to the resource name specified during initialization, or specify a new resource name here.

**current\_limit**

**current\_magnet**

**current\_max**

**current\_min**

**current\_rating**

**current\_supply**

**current\_target**

**field**

**field\_target**

**field\_units**

**get\_absorber** (*\*\*kwargs*)

**get\_coil\_const** (*\*\*kwargs*)

**get\_current\_limit** (*\*\*kwargs*)

**get\_current\_magnet** (*\*\*kwargs*)

**get\_current\_max** (*\*\*kwargs*)

**get\_current\_min** (*\*\*kwargs*)

**get\_current\_rating** (*\*\*kwargs*)

**get\_current\_supply** (*\*\*kwargs*)

**get\_current\_target** (*\*\*kwargs*)

**get\_field** (*\*\*kwargs*)

**get\_field\_target** (*\*\*kwargs*)

**get\_field\_units** (*\*\*kwargs*)

**get\_inductance** (*\*\*kwargs*)

**get\_persistent\_switch** (*\*\*kwargs*)

**get\_ramp\_num\_segments** (*\*\*kwargs*)

**get\_ramp\_rate\_units** (*\*\*kwargs*)

**get\_ramping\_state** (*\*\*kwargs*)

**get\_stability** (*\*\*kwargs*)

**get\_supply\_type** (*\*\*kwargs*)

**get\_voltage** (*\*\*kwargs*)

**get\_voltage\_limit** (*\*\*kwargs*)

**get\_voltage\_max** (*\*\*kwargs*)

**get\_voltage\_min** (*\*\*kwargs*)

**inductance**

**instrument\_type** = 'Magnet'

**pause** ()

Pauses the Model 430 Programmer at the present operating field/current.

**persistent\_switch**

**ramp** ()

Places the Model 430 Programmer in automatic ramping mode. The Model 430 will continue to ramp at the configured ramp rate(s) until the target field/current is achieved.

**ramp\_down** ()

Places the Model 430 Programmer in the MANUAL DOWN ramping mode. Ramping continues at the ramp rate until the Current Limit is achieved (or zero current is achieved for unipolar power supplies).

**ramp\_num\_segments**

**ramp\_rate\_units**

**ramp\_up** ()

Places the Model 430 Programmer in the MANUAL UP ramping mode. Ramping continues at the ramp rate until the Current Limit is achieved.

**ramping\_state**

**set\_absorber** (*val*, **\*\*kwargs**)

**set\_coil\_const** (*val*, **\*\*kwargs**)

**set\_current\_limit** (*val*, **\*\*kwargs**)

**set\_current\_rating** (*val*, **\*\*kwargs**)

**set\_current\_target** (*val*, **\*\*kwargs**)

**set\_field** (*val*)

Blocking field setter

**set\_field\_target** (*val*, **\*\*kwargs**)

**set\_field\_units** (*val*, **\*\*kwargs**)

**set\_persistent\_switch** (*val*, **\*\*kwargs**)

**set\_ramp\_num\_segments** (*val*, **\*\*kwargs**)

**set\_ramp\_rate\_units** (*val*, **\*\*kwargs**)

**set\_stability** (*val*, **\*\*kwargs**)

**set\_voltage\_limit** (*val*, **\*\*kwargs**)

**stability**

**supply\_type**

**voltage**

**voltage\_limit**

**voltage\_max**

**voltage\_min**

**zero()**

Places the Model 430 Programmer in ZEROING CURRENT mode. Ramping automatically initiates and continues at the ramp rate until the power supply output current is less than 0.1% of  $I_{max}$ , at which point the AT ZERO status becomes active.

### auspex.instruments.bbn module

**class** `auspex.instruments.bbn.APS` (*resource\_name=None, name='Unlabeled APS'*)

BBN APSI or DACII

**configure\_with\_proxy** (*proxy\_obj*)

**connect** (*resource\_name=None*)

**disconnect** ()

**get\_mixer\_correction\_matrix** ()

**get\_repeat\_mode** ()

**get\_run\_mode** ()

**get\_sampling\_rate** ()

**get\_sequence\_file** ()

**get\_trigger\_interval** ()

**get\_trigger\_source** ()

**get\_waveform\_frequency** ()

**instrument\_type** = 'AWG'

**load\_waveform** (*channel, data*)

**load\_waveform\_from\_file** (*channel, filename*)

**mixer\_correction\_matrix**

**repeat\_mode**

**run\_mode**

**sampling\_rate**

**sequence\_file**

**set\_amplitude** (*chs, value*)

**set\_mixer\_amplitude\_imbalance** (*chs, amp*)

**set\_mixer\_correction\_matrix** = None

**set\_mixer\_phase\_skew** (*chs, phase, SSB=0.0*)

**set\_offset** (*chs, value*)

**set\_repeat\_mode** (*mode*)

**set\_run\_mode** (*mode*)

**set\_sampling\_rate** (*freq*)

**set\_sequence\_file** (*filename*)

**set\_trigger\_interval** (*value*)

```
    set_trigger_source (source)
    set_waveform_frequency = None
    trigger()
    trigger_interval
    trigger_source
    waveform_frequency
class auspex.instruments.bbn.APS2 (resource_name=None, name='Unlabeled APS2')
    BBN APS2
    amp_factor
    configure_with_proxy (proxy_obj)
    connect (resource_name=None)
    disconnect ()
    fpga_temperature
    get_amp_factor ()
    get_fpga_temperature ()
    get_mixer_correction_matrix ()
    get_phase_skew ()
    get_run_mode ()
    get_sampling_rate ()
    get_sequence_file ()
    get_trigger_interval ()
    get_trigger_source ()
    get_waveform_frequency ()
    instrument_type = 'AWG'
    load_waveform (channel, data)
    mixer_correction_matrix
    phase_skew
    run_mode
    sampling_rate
    sequence_file
    set_amp_factor (amp)
    set_amplitude (chs, value)
    set_fpga_temperature = None
    set_mixer_correction_matrix (matrix)
    set_offset (chs, value)
    set_phase_skew (skew)
```

```

    set_run_mode(mode)
    set_sampling_rate(value)
    set_sequence_file(filename)
    set_trigger_interval(value)
    set_trigger_source(source)
    set_waveform_frequency(freq)
    trigger()
    trigger_interval
    trigger_source
    waveform_frequency
class auspex.instruments.bbn.TDM(resource_name=None, name='Unlabeled APS2')
    BBN TDM
    configure_with_proxy(proxy_obj)
    instrument_type = 'AWG'
class auspex.instruments.bbn.DigitalAttenuator(resource_name=None,
                                                name='Unlabeled Digital Attenuator')
    BBN 3 Channel Instrument
    NUM_CHANNELS = 3
    ch1_attenuation
    ch2_attenuation
    ch3_attenuation
    classmethod channel_check(chan)
        Assert the channel requested is feasible
    configure_with_proxy(proxy)
    connect(resource_name=None, interface_type=None)
        Either connect to the resource name specified during initialization, or specify a new resource name here.
    get_attenuation(chan)
    instrument_type = 'Attenuator'
    set_attenuation(chan, val)
class auspex.instruments.bbn.SpectrumAnalyzer(resource_name=None, *args, **kwargs)
    BBN USB Spectrum Analyzer
    IF_FREQ = 10700000.0
    connect(resource_name=None, interface_type=None)
        Either connect to the resource name specified during initialization, or specify a new resource name here.
    get_voltage()
    instrument_type = 'Spectrum analyzer'
    peak_amplitude()
    voltage

```

**auspex.instruments.binutils module**

**auspex.instruments.bnc module**

**auspex.instruments.hall\_probe module**

**auspex.instruments.holzworth module**

**auspex.instruments.instrument module**

**class** `auspex.instruments.instrument.Instrument`

**configure\_with\_dict** (*settings\_dict*)

Accept a settings dictionary and attempt to set all of the instrument parameters using the key/value pairs.

**configure\_with\_proxy** (*proxy*)

**connect** (*resource\_name=None*)

**disconnect** ()

**auspex.instruments.interface module**

**class** `auspex.instruments.interface.Interface`

Currently just a dummy interface for testing.

**close** ()

**query** (*value*)

**values** (*query*)

**write** (*value*)

**class** `auspex.instruments.interface.PrologixInterface` (*resource\_name*)

Prologix-Ethernet interface for communicating with remote GPIB instruments.

**class** `auspex.instruments.interface.VisaInterface` (*resource\_name*)

PyVISA interface for communicating with instruments.

**CLS** ()

**ESE** ()

**ESR** ()

**IDN** ()

**OPC** ()

**RST** ()

**SRE** ()

**STB** ()

**TST** ()

**WAI** ()

**close** ()



```

query (query_string)
query_ascii_values (query_string, **kwargs)
query_binary_values (query_string, container=<built-in function array>, datatype='h',
                       is_big_endian=False)
read ()
read_bytes (count, chunk_size=None, break_on_termchar=False)
read_raw (size=None)
value (query_string)
values (query_string)
write (write_string)
write_binary_values (query_string, values, **kwargs)
write_raw (raw_string)

```

**auspex.instruments.keithley module**

**auspex.instruments.kepcos module**

**auspex.instruments.keysight module**

**auspex.instruments.lakeshore module**

**auspex.instruments.lecroy module**

**auspex.instruments.magnet module**

**auspex.instruments.picosecond module**

**auspex.instruments.prologix module**

```

class auspex.instruments.prologix.PrologixSocketResource (ipaddr=None,
                                                         gpib=None)

```

A resource representing a GPIB instrument controlled through a Prologix GPIB-ETHERNET controller. Mimics the functionality of a pyVISA resource object.

See <http://prologix.biz/gpib-ethernet-controller.html> for more details and a utility that will discover all prologix instruments on the network.

**timeout**

Timeout duration for TCP comms. Default 5s.

**write\_termination**

Character added to each outgoing message.

**read\_termination**

Character which denotes the end of a response message.

**idn\_string**

GPIB identification command. Defaults to ‘\*IDN?’

**bufsize**

Maximum amount of data to be received in one call, in bytes.

**close()**

Close the connection to the Prologix.

**connect** (*ipaddr=None, gpib=None*)

Connect to a GPIB device through a Prologix GPIB-ETHERNET controller. box.

**Parameters**

- **ipaddr** – The IP address of the Prologix GPIB-ETHERNET.
- **gpib** – The GPIB address of the instrument to be controlled.

**Returns** None.

**query** (*command*)

Query instrument with ASCII command then read response.

**Parameters** **command** – Message to be sent to instrument.

**Returns** The instrument data with termination character stripped.

**query\_ascii\_values** (*command, converter='f', separator=', ', container=<class 'list'>, bufsize=None*)

Write a string message to device and return values as iterable.

**Parameters**

- **command** – Message to be sent to device.
- **values** – Data to be written to device (as an iterable)
- **converter** – String format code to be used to convert values.
- **separator** – Separator between values – data.split(separator).
- **container** – Iterable type to use for output.
- **bufsize** – Number of bytes to read from instrument. Defaults to resource
- **if None.** (*bufsize*) –

**Returns** Iterable of values converted from instrument response.

**query\_binary\_values** (*command, datatype='f', container=<built-in function array>, is\_big\_endian=False, bufsize=None*)

Write a string message to device and read binary values, which are returned as iterable. Uses a pyvisa utility function.

**Parameters**

- **command** – String command sent to instrument.
- **values** – Data to be sent to instrument.
- **datatype** – Format string for single element.
- **container** – Iterable to return number of as.
- **is\_big\_endian** – Bool indicating endianness.

**Returns** Iterable of data values to be returned

**read()**

Read an ASCII value from the instrument.

**Parameters** None. –

**Returns** The instrument data with termination character stripped.

**read\_raw** (*bufsize=None*)

Read bytes from instrument.

**Parameters**

- **bufsize** – Number of bytes to read from instrument. Defaults to resource
- **if None.** (*bufsize*) –

**Returns** Instrument data. Nothing is stripped from response.

**timeout**

**write** (*command*)

Write a string message to device in ASCII format.

**Parameters** **command** – The message to be sent.

**Returns** The number of bytes in the message.

**write\_ascii\_values** (*command, values, converter='f', separator=', '*)

Write a string message to device followed by values in ASCII format.

**Parameters**

- **command** – Message to be sent to device.
- **values** – Data to be written to device (as an iterable)
- **converter** – String format code to be used to convert values.
- **separator** – Separator between values – separator.join(data).

**Returns** Total number of bytes sent to instrument.

**write\_binary\_values** (*command, values, datatype='f', is\_big\_endian=False*)

Write a string message to device followed by values in binary IEEE format using a pyvisa utility function.)

**Parameters**

- **command** – String command sent to instrument.
- **values** – Data to be sent to instrument.
- **datatype** – Format string for single element.
- **is\_big\_endian** – Bool indicating endianness.

**Returns** Number of bytes written to instrument.

**write\_raw** (*command*)

Write a string message to device as raw bytes. No termination character is appended.

**Parameters** **command** – The message to be sent.

**Returns** The number of bytes in the message.

**auspex.instruments.rfmd module**

**auspex.instruments.stanford module**

**auspex.instruments.tektronix module**

## auspex.instruments.vaunix module

## auspex.instruments.X6 module

```
class auspex.instruments.X6.X6Channel (receiver_channel=None)
    Channel for an X6

    set_by_receiver_channel (receiver)

class auspex.instruments.X6.X6 (resource_name=None, name='Unlabeled X6',
                                gen_fake_data=False)
    BBN QDSP running on the II-X6 digitizer

    acquire_mode
    add_channel (channel)
    channel_setup (channel)
    configure_with_dict (settings_dict)
        Accept a ssettings dictionary and attempt to set all of the instrument parameters using the key/value pairs.
    connect (resource_name=None)
    data_available ()
    disconnect ()
    done ()
    get_buffer_for_channel (channel)
    get_socket (channel)
    instrument_type = 'Digitizer'
    number_averages
    number_segments
    number_waveforms
    receive_data (channel, oc, exit, ready, run)
    record_length
    reference
    spew_fake_data (counter, ideal_data, random_mag=0.1, random_seed=12345)
        Generate fake data on the stream. For unittest usage. ideal_data: array or list giving means of the expected
        signal for each segment

        Returns the total number of fake data points, so that we can keep track of how many we expect to receive,
        when we're doing the test with fake data

    wait_for_acquisition (dig_run, timeout=15, ocs=None, progressbars=None)
```

## auspex.instruments.yokogawa module

## Module contents

## auspex.qubit package

## Submodules

`auspex.qubit.pipeline` module

`auspex.qubit.qubit_exp` module

`auspex.qubit.mixer_calibration` module

`auspex.qubit.pulse_calibration` module

`auspex.qubit.single_shot_fidelity` module

## Module contents

### 3.6.2 `auspex.config` module

`auspex.config.isnotebook()`

`auspex.config.load_db()`

### 3.6.3 `auspex.data_format` module

**class** `auspex.data_format.AuspexDataContainer` (*base\_path, mode='a', open\_all=True*)

A container for Auspex data. Data is stored as *datasets* which may be of any dimension. These are in turn organized by *groups* which can be used to store related information. Data is stored as a binary file plus a json metafile which describes the dimension and type of data stored.

Example organization

**DataContainer:**

- QubitOneGroup
  - | - DemodulatedData
  - | - ThresholdedData
- QubitTwoGroup | - RawData | - DemodulatedData

**close()**

Close the data container.

**new\_dataset** (*groupname, datasetname, descriptor*)

Add a dataset to a specific group.

**Parameters**

- **groupname** – Name of the group to which to add the dataset.
- **datasetname** – Name of the dataset to be added.
- **descriptor** – *DataStreamDescriptor* that describes the dataset that is to be added.

**new\_group** (*groupname*)

Add a group to the data container.

**Parameters** **groupname** – Name of the data group to be added to the data container.

**open\_all()**

Open all of the datasets contained in this DataContainer. This also populates the list of groups.

**Returns** A dictionary of all of the datasets, which each item as an (array, descriptor) tuple.

**open\_dataset** (*groupname*, *datasetname*)

Open a particular dataset stored in this DataContainer.

**Parameters**

- **groupname** – The group name of the data that is to be opened.
- **datasetname** – The name of the dataset that is to be opened.

**Returns** A numpy array of the data stored. desc: *DataStreamDescriptor* for the data stored.

**Return type** data

### 3.6.4 auspex.experiment module

### 3.6.5 auspex.log module

`auspex.log.in_jupyter()`

### 3.6.6 auspex.parameter module

```
class auspex.parameter.BoolParameter (name=None,          unit=None,          default=None,
                                         value_range=None,  allowed_values=None,  incre-
                                         ment=None, snap=None)
```

**value**

```
class auspex.parameter.FileNameParameter (*args, **kwargs)
```

```
class auspex.parameter.FloatParameter (name=None,          unit=None,          default=None,
                                         value_range=None,  allowed_values=None,  incre-
                                         ment=None, snap=None)
```

**value**

```
class auspex.parameter.IntParameter (name=None,          unit=None,          default=None,
                                       value_range=None,  allowed_values=None,  incre-
                                       ment=None, snap=None)
```

**value**

```
class auspex.parameter.Parameter (name=None, unit=None, default=None, value_range=None,
                                   allowed_values=None, increment=None, snap=None)
```

Encapsulates the information for an experiment parameter

**add\_post\_push\_hook** (*hook*)

**add\_pre\_push\_hook** (*hook*)

**assign\_method** (*method*)

**dict\_repr** ()

Return a dictionary representation. Intended for Quince interop.

**push** ()

**value**

```
class auspex.parameter.ParameterGroup(params, name=None)
    An array of Parameters

    assign_method(methods)

    push()

    value
```

### 3.6.7 auspex.stream module

```
class auspex.stream.DataAxis(name, points=[], unit=None, metadata=None, dtype=<class
                                'numpy.float32'>)
```

An axis in a data stream

```
    add_points(points)

    data_type(with_metadata=False)

    num_points()

    points_with_metadata()

    reset()

    tuple_width()
```

```
class auspex.stream.DataStream(name=None, unit=None)
```

A stream of data

```
    done()

    final_init()

    num_points()

    percent_complete()

    pop()

    push(data)

    push_event(event_type, data=None)

    reset()

    set_descriptor(descriptor)
```

```
class auspex.stream.DataStreamDescriptor(dtype=<class 'numpy.float32'>)
```

Axes information

```
    add_axis(axis, position=0)

    add_param(key, value)

    axes_done()

    axis(axis_name)

    axis_data_type(with_metadata=False, excluding_axis=None)

    axis_names(with_metadata=False)
        Returns all axis names included those from unstructured axes

    axis_num(axis_name)

    copy()
```

```

data_axis_values ()
    Returns a list of point lists for each data axis, ignoring sweep axes.

data_dims ()

dims ()

done ()

expected_num_points ()

expected_tuples (with_metadata=False, as_structured_array=True)
    Returns a list of tuples representing the cartesian product of the axis values. Should only be used with
    non-adaptive sweeps.

extent (flip=False)
    Convenience function for matplotlib.imshow, which expects extent=(left, right, bottom, top).

is_adaptive ()

last_data_axis ()

num_data_axis_points ()

num_dims ()

num_new_points_through_axis (axis_name)

num_points ()

num_points_through_axis (axis_name)

pop_axis (axis_name)

reset ()

tuple_width ()

tuples (as_structured_array=True)
    Returns a list of all tuples visited by the sweeper. Should only be used with adaptive sweeps.

class auspex.stream.InputConnector (name="", parent=None, datatype=None,
                                     max_input_streams=1)

    add_input_stream (stream)

    done ()

    num_points ()

    update_descriptors ()

class auspex.stream.OutputConnector (name="", data_name=None, unit=None, parent=None,
                                       dtype=<class 'numpy.float32'>)

    add_output_stream (stream)

    done ()

    num_points ()

    push (data)

    push_event (event_type, data=None)

    set_descriptor (descriptor)

    update_descriptors ()
    
```



```
class auspex.stream.SweepAxis(parameter, points=[], metadata=None, refine_func=None, call-  
                             back_func=None)
```

Structure for sweep axis, separate from DataAxis. Can be an unstructured axis, in which case ‘parameter’ is actually a list of parameters.

```
check_for_refinement (output_connectors_dict)
```

Check to see if we need to perform any refinements. If there is a refine\_func and it returns a list of points, then we need to extend the axes. Otherwise, if the refine\_func returns None or false, then we reset the axis to its original set of points. If there is no refine\_func then we don’t do anything at all.

```
push ()
```

Push parameter value(s)

```
update ()
```

Update value after each run.

```
auspex.stream.cartesian(arrays, out=None, dtype='f')
```

<http://stackoverflow.com/questions/28684492/numpy-equivalent-of-itertools-product>

### 3.6.8 auspex.sweep module

```
class auspex.sweep.Sweeper
```

Control center of sweep axes

```
add_sweep (axis)
```

```
check_for_refinement (output_connectors_dict)
```

```
done ()
```

```
is_adaptive ()
```

```
swept_parameters ()
```

```
update ()
```

Update the levels



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