Pynapse Manual for v95 Synapse

Python Programming in Synapse

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Overview

Pynapse is a gizmo for tightly integrating Python coding into your Synapse experiment.

Many users write external code in Python (or Matlab) that runs alongside their Synapse experiments. These programs are used for overall experiment control, stimulus delivery, behavioral control, and online analysis - things that are either novel paradigms that don't exist in the current gizmo set or can't easily be programmed to run directly on the real-time hardware.

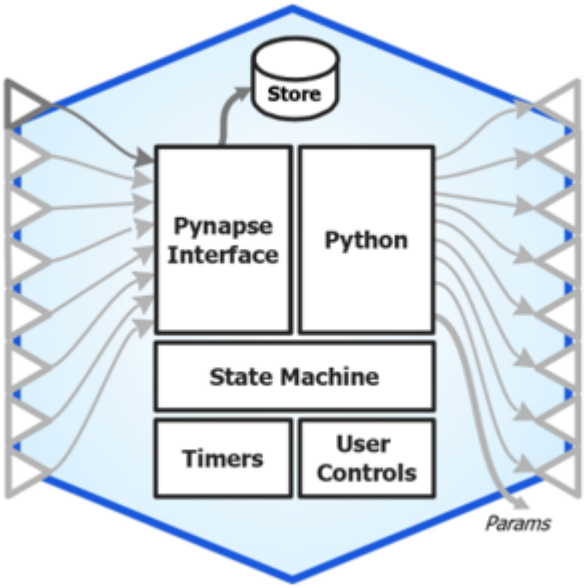
There are several challenges faced by these users and Pynapse is designed to address these issues with an intuitive and powerful interface.

Benefits of Pynapse

Pynapse is more than a great embedded Python editor within Synapse. You get:

- Great Python editor with all the bells and whistles (highlighting, code completion, and more)
- Easy-to-learn, structured programming framework
- Fully automatic Synapse synchronization. Your Python code is saved and versioned with your experiment
- Powerful hardware and software seamlessly integrated
- Runtime live code editing and monitoring
- Automatic code flowcharting

Pynapse Gizmo



Pynapse Gizmo Block Diagram

All of this is built into the Pynapse gizmo. Just install Python and drop the Pynapse gizmo into your Synapse experiment.

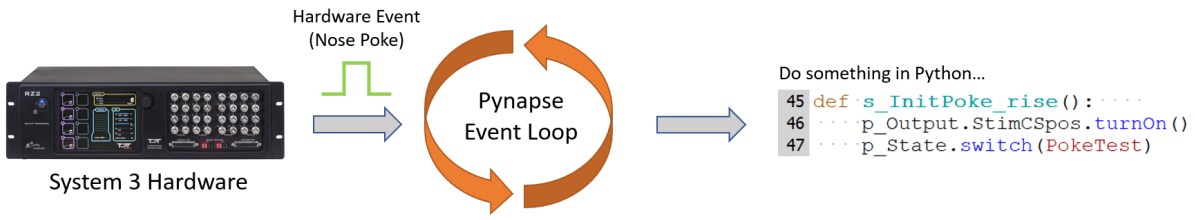
The circuit that runs on the real-time hardware has all the features that anyone writing custom Python code to interact with the hardware. Pynapse runs an optimized polling loop that synchronizes Python to Synapse, faster than existing methods. The State Machine architecture in Pynapse yields tight programs that are easy to read and easy to debug.

Event Loop

A tight polling loop is continuously running and monitoring hardware events defined in the experiment.

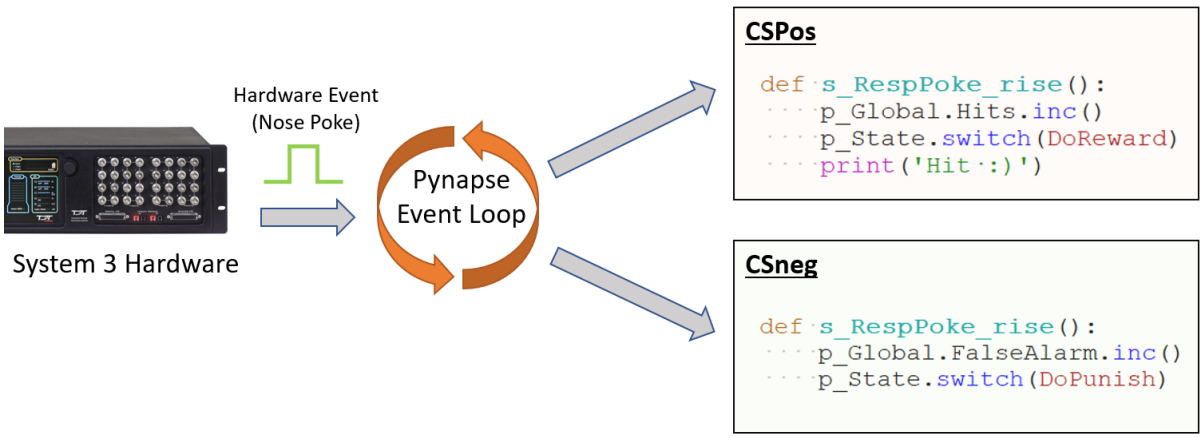
1. Hardware event is detected by the Pynapse event loop.
2. Call is made into Python to execute a method written by the user
3. Call is logged and timestamped
4. Events are sent back to the hardware

All of this happens in milliseconds.



Python State Machine

The Python code can be organized into 'States'. Pynapse keeps track of which state it is in, and hardware events will only trigger Python calls defined within that state. State changes are also controlled by the Python code, and automatically timestamped and stored with the rest of your data for easy analysis.



Main Assets of Pynapse Gizmo

Pynapse has six fundamental assets built into it that are accessible in the Python code.

Asset	Description
Inputs	Connect to external hardware and trigger events while accessing signals in Python
Outputs	Drive logic and waveform outputs under Python control
Timers	Drive timing of Python program or an experimental event
Controls	Provide user control with standard User Interface elements
Globals	Share global variables across your Python code and sync to edit runtime user controls
States	Switch states, set timeouts, or capture state change events

Common Applications

Program Control

- Start/stop Synapse or other programs based on conditional triggers
- Run Synapse for a set duration

Behavioral Control

- Implement complex behavioral paradigms over trials that control:
  - Cues
  - Waiting periods
  - Input decisions
  - Reward output
  - and more

Signal Analysis and Display

- Collect signals in a triggered buffer or through the API
- Perform calculations, such as:
  - Presentation averaging, spike counting, or FFT
- Plot results using Python plotting libraries (such as Matplotlib)

Stimulus Presentation

- Generate simple or complex stimuli to present during triggered conditions using Pynapse output control or built-in buffers

Requirements

Installing Python

After installing TDT drivers and Synapse, you'll need to install Python on the computer that is running Synapse. Pynapse works with Python 3.x.

There are two recommended paths for installing Python:

- Anaconda Python: Anaconda includes many scientific packages pre-installed for you and is the recommended installation. It is easier to create and manage environments in Anaconda as well.
- Standard Python: If you just want to run Python inside Synapse for behavioral control, install standard Python.

This document covers the Anaconda installation method. For the standard Python installation method click here.

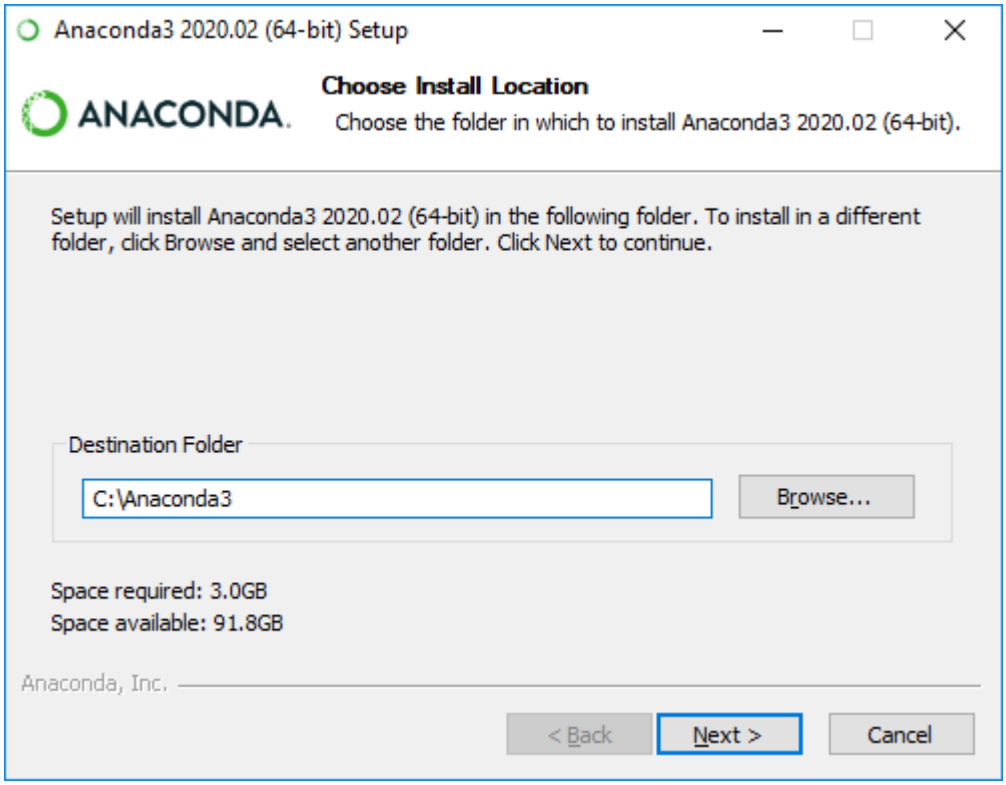
Anaconda Python Installation

Anaconda installs from https://docs.anaconda.com/anaconda/install/windows/

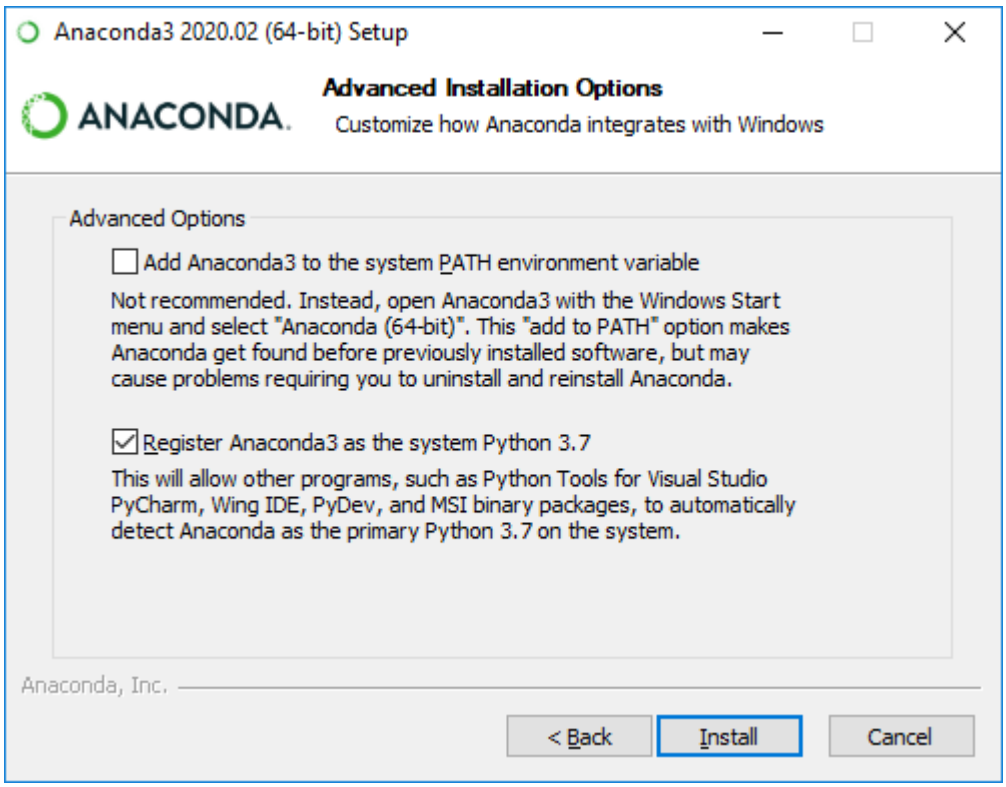
> **Note**
>
> We recommend installing 64-bit Python on 64-bit Windows 10. This is the Python 3.x86 "64-Bit Graphical Installer" option.
>
> On 32-bit machines, install the Python 3.x "32-Bit Graphical Installer".

1. During installation:
    a. Select 'Install for All Users'
    b. Change the installation directory to C:\Anaconda3

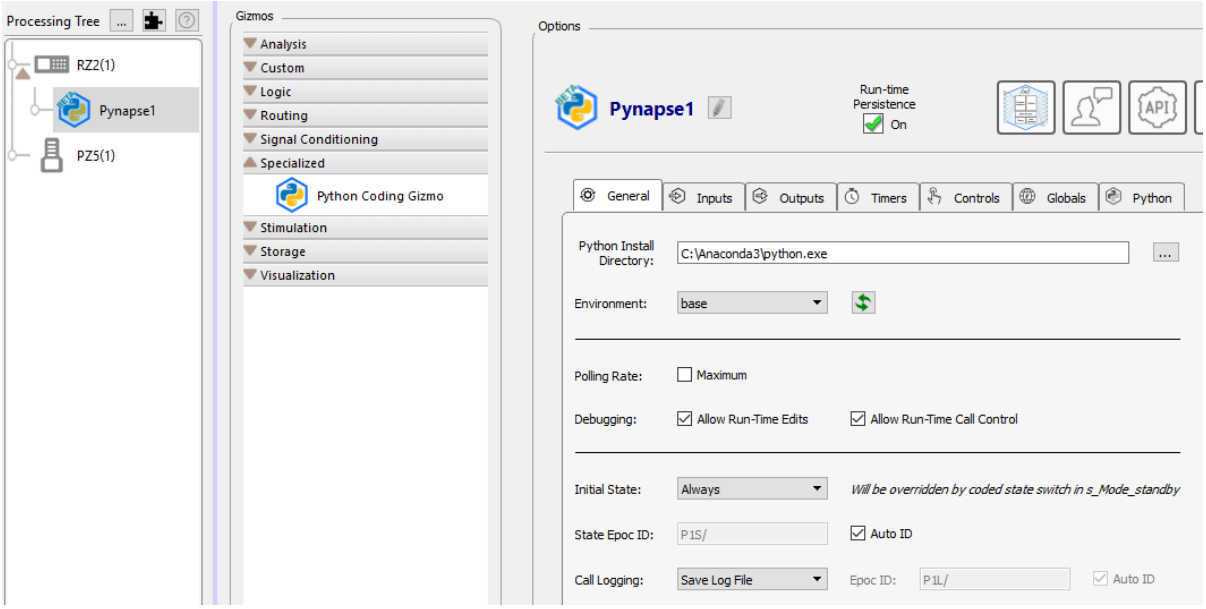
Example Installer 1



Example Installer 2



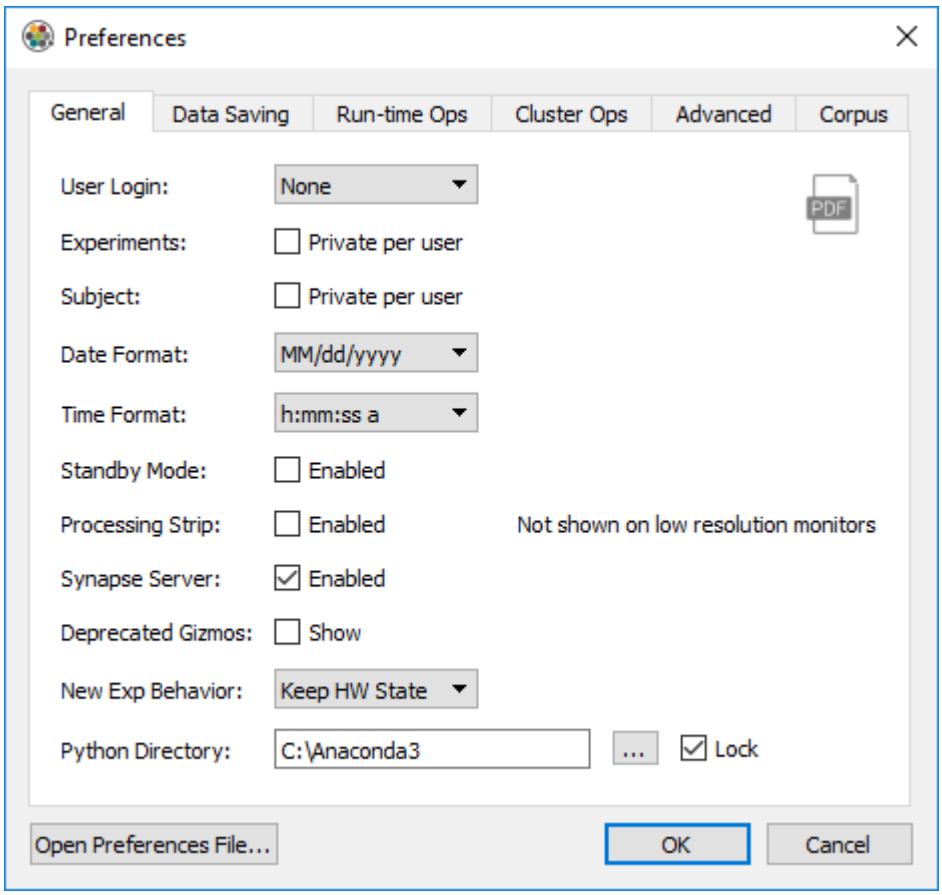
2. In Synapse, add a Python Coding Gizmo from the Specialized gizmo list.



3. In Pynapse General Tab, set the Python Install Directory to your installed Python, which in this case is:

   `C:\Anaconda3\python.exe`

4. In Synapse, go to Menu → Preferences. The Python Directory will have updated to the path you just used. Select 'Lock' so this path is the default path whenever you use a Pynapse gizmo.



Environments

Pynapse also works in Python virtual environments. A virtual environment is a self-contained directory tree that contains a Python installation for a particular version of Python, plus a number of additional packages. The default environment is called 'base'.

Environments are simply directories on disk, so it is easy to delete/recreate environments if they get in a bad state. It is more difficult to do this with the 'base' environment. It is therefore recommended that you create a specific environment for Pynapse to use.

Environments are created in Anaconda using an Anaconda Prompt. Note that you can specify the Python version for each environment as well.

Here's how to create an environment to use in Pynapse:

1. In Windows, go to Start → "Anaconda Prompt (Anaconda3)"
2. Type this to create a Python 3.7 environment called 'pynapse':

   `conda create --name pynapse python=3.7`

   > **Tip**
   >
   > If you want to add runtime plotting to Pynapse, create the environment with this:
   >
   > `conda create --name pynapse python=3.7 matplotlib ipykernel=4.10.0`

3. The fresh environment is mostly empty, so you'll want to add common packages. From the Anaconda Prompt, first type this to activate the new environment:

   `conda activate pynapse`

4. Then install some of the libraries we'll want to use. For example, install the tdt package for data analysis:

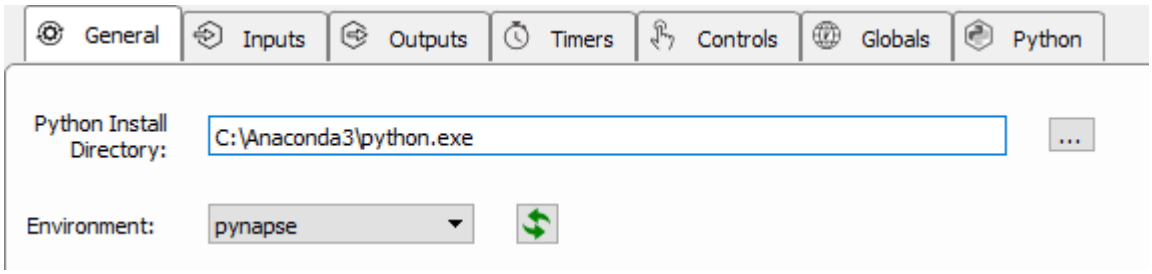
   `pip install tdt`

   > **Important**
   >
   > Anytime you want to add packages to an environment, do it through the Anaconda Prompt and activate your environment first.

5. To make sure auto-completion on the Pynapse editor works, you must downgrade one of the installed packages:

```
pip install jedi==0.17.0
```

6. Back in Synapse, the Pynapse General Tab has a drop down that shows the environments created in Anaconda, so you can choose the environment directly in the GUI.



Quick Start Example

In this example we want to turn a light on with the capture of a button press, and then turn the light off when the button is released. We will have a single input for our button ('Button') and a single output for the light ('Light'). If you were to code this in Python, it might look something like this:

```
import time

while True:

    print('WaitState entered')

    # turn off output
    Light.off()

    # wait until button is pressed
    while Button.false():
        time.sleep(.01)

    print('OnState entered')

    # turn on output
    Light.on()

    # wait until button is false
    while Button.true():
        time.sleep(.01)

    # go back to beginning
```

In Pynapse, instead of using a while loop, we define things called States that can call upon specified methods that we call Slot Methods and Asset Methods when certain hardware events occur. Pynapse knows the current State and is constantly polling the inputs directly from the hardware in a tight loop. When a hardware event occurs that has a matching Slot Method in the current State, that Slot Method gets triggered. The result of this is simplicity in how your state machine is coded - instead of using embedded while loops and conditional statements, you can simply use States and integrated Slot Methods and Asset Methods to issue commands and move from one state to another depending on what events have occurred on the hardware or outputs of code calculations.

Here is a table of important definitions of terms you will see throughout this example and in the Pynapse manual:

Term	Definition
state	Specially defined Python class that has `#StateId = ?` at the end of the class definition
method	Any function defined inside a class using the `def` keyword
slot method	Special method that Pynapse calls in response to events. Slot method names always begin with a `s_` prefix
asset	Special Pynapse classes that interact with inputs, outputs, states, controls, globals, and timers. Assets always begins with a `p_` prefix. For reference, the list of all slot methods that these assets can trigger, and methods you can use to interact with the assets in Python, can be found in the Assets Reference section of this manual.
function	General name used for any function defined outside of a class with the `def` keyword

For the quick start example, we are going to demonstrate how to perform our Light on/off task in two ways: the first is going to use the initial 'Always' State in Pynapse; the second is going to show you how to use multiple States to switch between active pieces of code and perform certain tasks based on captured hardware events.

Using the Always State

The special State called 'Always' runs on every polling loop regardless of what the Pynapse active State is. In our example, we can take advantage of this special State by just focusing on writing code that triggers based on hardware events and not worrying about the Pynapse State machine. Since the 'Always' State is present in the Pynapse Source by default, all we write are Sloth Methods and Asset Methods:

```
# Pynapse Source #

class Always:   #StateID = 0

    def s_Button_rise():
        p_Output.Light.turnOn()
        print('Light is on!')

    def s_Button_fall():
        p_Output.Light.turnOff()
        print('Light is off!')
```

A high-level translation of this code would read as follows:

In the Always State, if the 'Button' input true (button is pressed), then turn the 'Light' output on and print "Light is on!"; if the 'Button' input is false (button is released), then turn the 'Light' output off and print "Light is off!".

Here is the same translation using Pynapse terminology:

As mentioned, Pynapse is constantly polling the hardware for events that trigger methods inside of the current active State (Always). In this case, we've defined two Slot Methods 's_Button_rise' and 's_Button_fall' which are part of the Input Assets. The 's_Button_rise' Slot Method triggers when the button is pressed (Button input changes to true) and the 's_Button_fall' triggers when the button is released (Button input changes from true to false). When the button press is detected, Pynapse internally executes the Output Pynapse Asset Method (Light.turnOn), which toggles the output logic signal from low to high. When the button is released, the Light.turnOff Asset Method is executed.

> **Note**
>
> If the button was released first (e.g you were pressing down the button as you went to run-time then let go) the 's_Button_fall' Slot Method would trigger first. These Slot Methods are independent functions that are beholden only to detected hardware events - they do not influence each other.

> **Important**
>
> All Pynapse Slot Methods start with `s_` and all Pynapse Assets start with `p_`. Remembering these two prefixes makes it easy to use code completion inside the Pynapse Code Editor to see all the available Slots and Assets right inside the editor and quickly find what you are looking for.

After we test this code (right-click 'Main' → 'Test') and go to run-time, you will see the Light output toggle on and off with the pressing or release of the Button input.

Using Multiple States

This example was entirely coded in the Always State. Now, we'll take advantage of Pynapse's built-in State Machine. Using multiple Pynapse States has major advantages at runtime, especially as your paradigm increases in complexity. You get a visual indicator of what State you are in for behavior monitoring and the State changes are timestamped and recorded in the data tank synchronized with the rest of your data. There are some other debugging features you get at run-time as well, discussed in more detail in Run-Time and Debugging.

Here we define three states: Always, WaitState and LightOn. When moving to run-time (Standby, Preview, or Record mode) Pynapse enters the Always State and the 's_Mode_recprev' Slot Method is triggered. This is a Synapse Control Slot Method that detects when Synapse has changed mode from Idle to Preview or Record. Once 's_Mode_recprev' is triggered the 'p_State.switch(WaitState)' Asset Method is executed. This key asset tells Pynapse to move to a new State.

```
# Pynapse Source #

class Always:   #StateID = 0

    def s_Mode_recprev():
        p_State.switch(WaitState)
```

Next, Pynapse enters WaitState and immediately runs a specially named Slot Method called 's_State_Enter'. In this example, the s_State_Enter Slot Method turns off the Output (Light) by executing the 'p_Output.Light.turnOff' Output Asset and prints our familiar string.

Now, just like in the first example that only used the Always State, we monitor hardware events and wait for the Input (Button) to become true, wherein another switch Asset Method is executed and we move to our third State (LightOn).

> **Note**
>
> While WaitState is our active State a release of the button will not do anything since there are no Slot Methods in WaitState that detect falling-edge hardware events.

```
class WaitState:   #StateID = ?

    def s_State_enter():
        p_Output.Light.turnOff()
        print('Light is off!')

    def s_Button_rise():
        p_State.switch(LightOn)
```

Finally, we enter the LightOn State. As we enter, the 's_State_enter' Slot Method is triggered and the 'p_Output.Light.turnOn' Asset Method is executed. As you can see, coordinating output events to State changes is a simple way to write conditional events in the Pynapse State Machine. Similarly to the WaitState, Pynapse will continue polling until the 's_Button_fall' Slot

Method is triggered by a button release, wherein we switch back to WaitState and the Output (Light) is turned off.

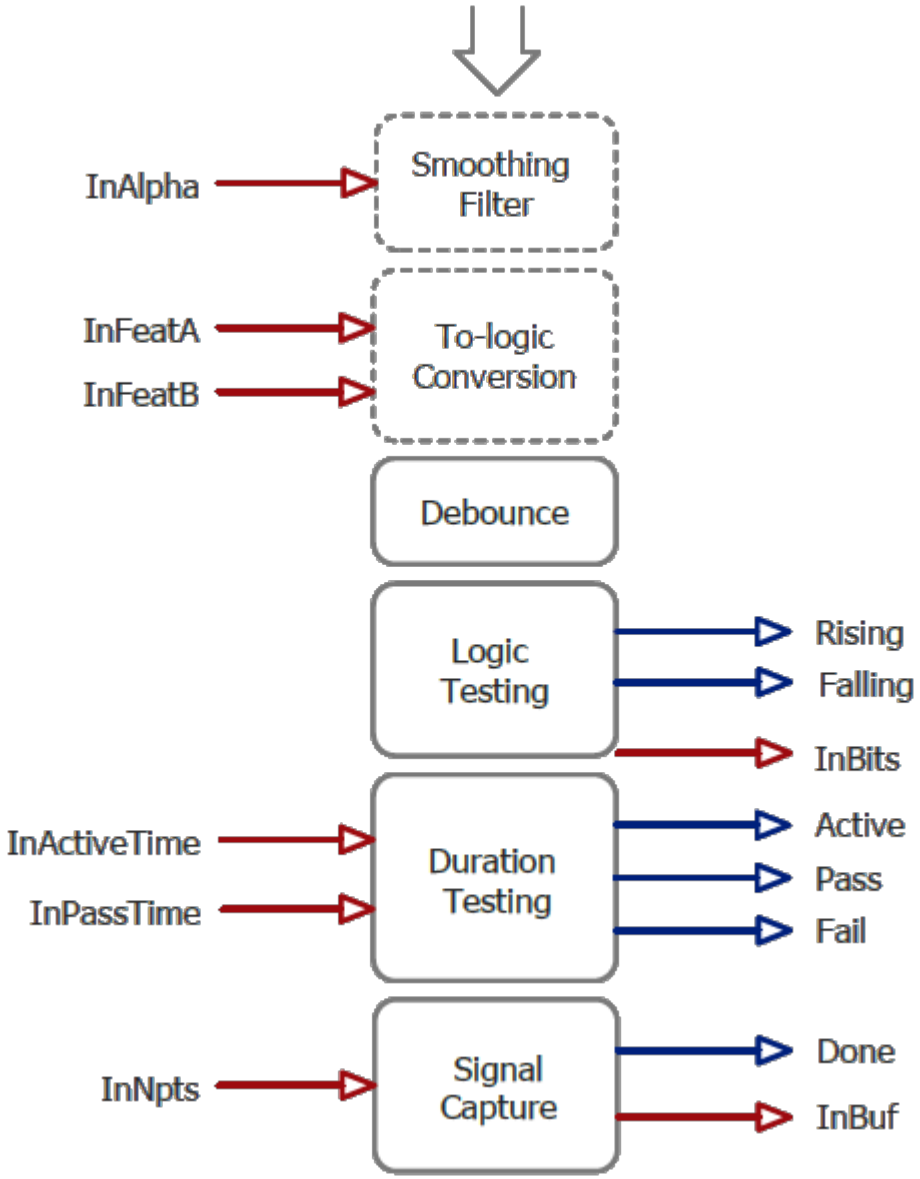
```
class LightOn:   #StateID = ?

    def s_State_enter():
        p_Output.Light.turnOn()
        print('Light is on!')

    def s_Button_fall():
        p_State.switch(WaitState)
```

Important

Notice there were no `while` loops used in these examples. In Pynapse you should almost never write `while` loops. Its polling loop handles this for you. All of your methods should return immediately so the polling loop can continue executing.

Inputs

You can have up to 8 inputs into the Pynapse gizmo. These inputs can be digital signals (logic TTL) or analog signals (float or integer) that go through a Logic Conversion, such as thresholding.



Input Processor

Set the **Name** of the input to something that makes sense for your experiment, e.g. 'NosePoke'. This will be used throughout the Python code.

You can optionally save epoch timestamp events for each input. An integer code for the event type is stored with the timestamp. See Epoc Storage below for more information.

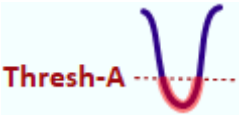
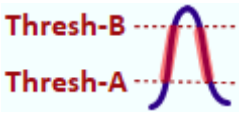
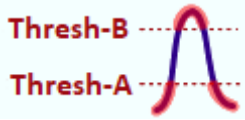
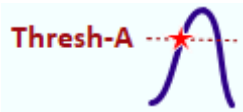
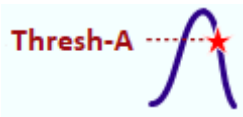
Logic Conversion for Number Signals

Number input signals pass through a logic conversion so they can trigger on/off events in Pynapse.

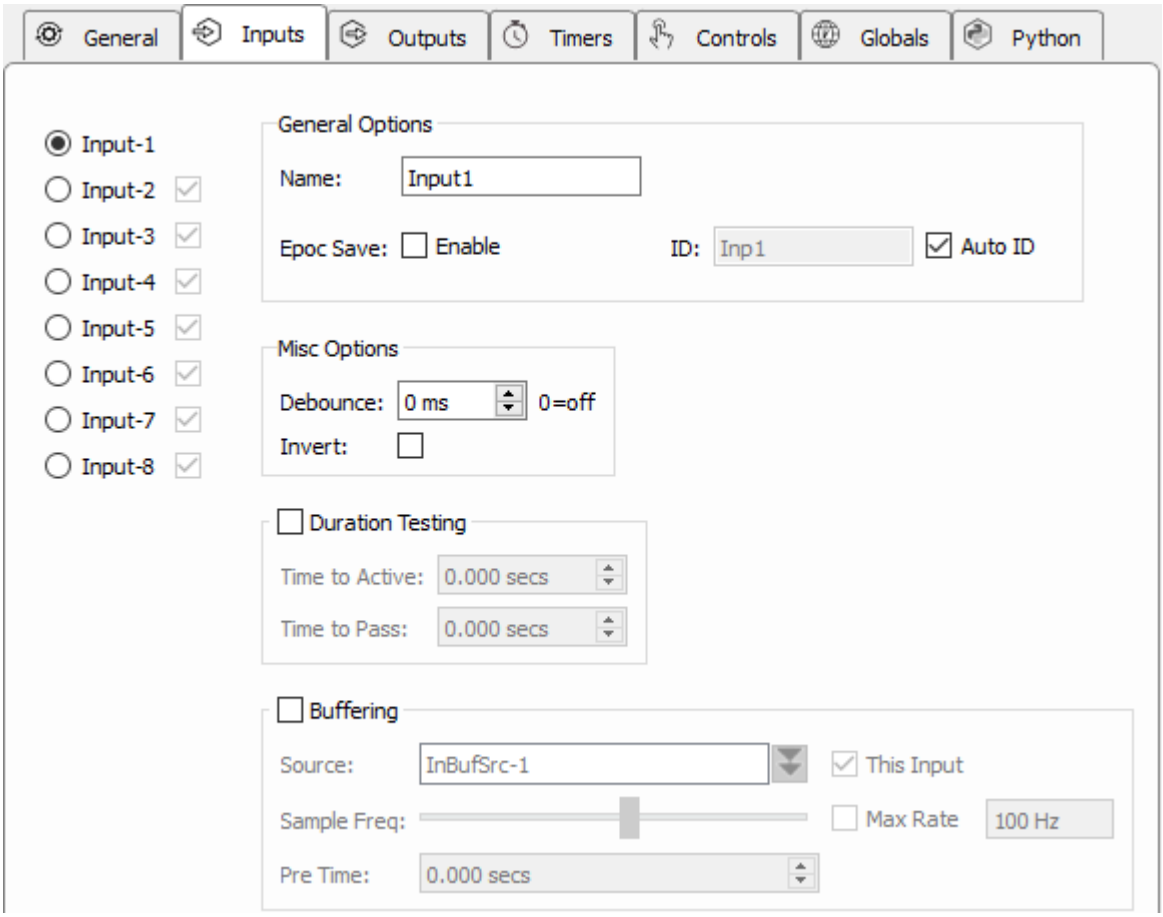
Smoothing is a low pass filter that removes jitter on the analog signal before logic conversion. This helps avoid a situation where the signal is quickly bouncing around the test threshold.

By default, the **Test** is **Above**, which is a simple threshold detection method to convert the number signal input into a logic signal when it goes beyond the **Thresh-A** value.

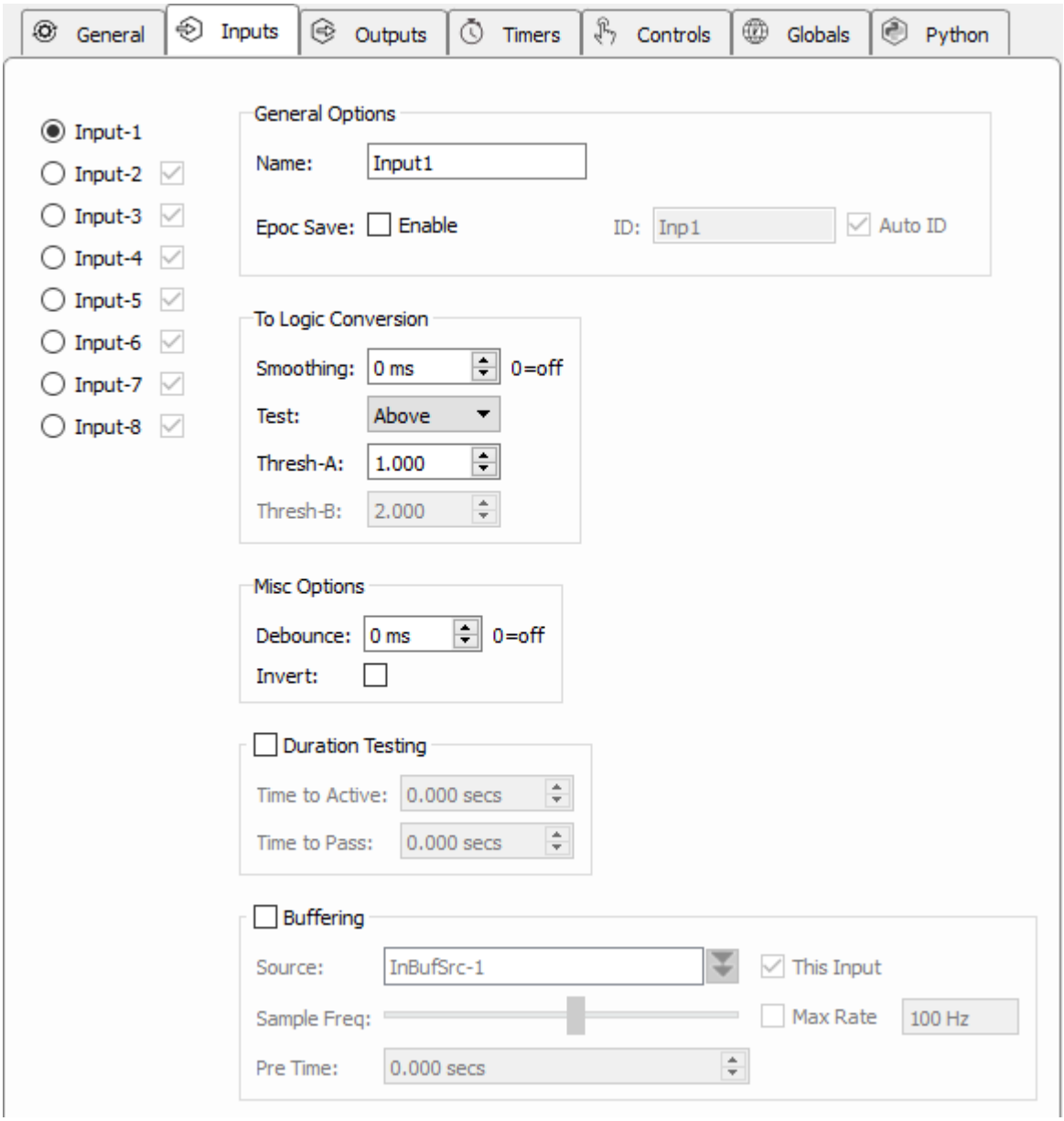
Epoc events are triggered on the 'rise' event of all of these tests. If the test can be true for more than 2 samples ('Strobe') then a timestamp for the 'fall' event is also stored. See Epoc Storage below for full epoc code information.

Test Type		Description	Duration
Above		Signal is above Thresh-A	Strobe
Below		Signal is below Thresh-A	Strobe
Between		Signal is between Thresh-A and Thresh-B	Strobe
Outside		Signal is outside Thresh-A and Thresh-B	Strobe
Rising		Signal is increasing in value	Strobe
Falling		Signal is decreasing in value	Strobe
Peak		Signal forms a local peak	Trigger
Valley		Signal forms a local valley	Trigger
Tip		Signal forms a local peak or valley	Trigger
Rise Thru		Signal rises through Thresh-A from below	Trigger
Fall Thru		Signal falls through Thresh-A from above	Trigger
Pass Thru		Signal passes through Thresh-A from above or below	Trigger

Inputs Tab - Logic Options



Inputs Tab - Number Options



Invert and **Debounce** are typically used if the input is coming directly from a digital input on the RZ processor. **Debounce** is the amount of time the input has to settle before its new state is used. This is useful for lever presses or hardware button presses which can 'bounce' on contact and trigger several rapid artificial events before making solid contact.

Slot Methods for Responding to Input States

These input slots capture status information about the inputs. They are available as method definitions inside Pynapse states for each input. Write a method with this name to react to the corresponding event.

Slot name	Operation	Event
s_Input1_true()	Status	input is true
s_Input1_rise()	Status	input changed to true
s_Input1_fall()	Status	input changed to false
s_Input1_active()	Duration	input passed the 'Time to Active' duration test (see Duration Testing)
s_Input1_pass()	Duration	input passed the 'Time to Pass' duration test (see Duration Testing)
s_Input1_fail()	Duration	input failed the 'Time to Pass' duration test, after passing 'Time to Active' (see Duration Testing)
s_Input1_done()	Buffer	input buffer is full and ready to be read (see Buffering)

Note

'Input1' is default name of the first input. The name of each slot method gets replaced with the name of your actual input, so if you name the input 'NosePoke' then s_NosePoke_rise() is an available slot

Example

Move through behavioral states based on status of MyInput

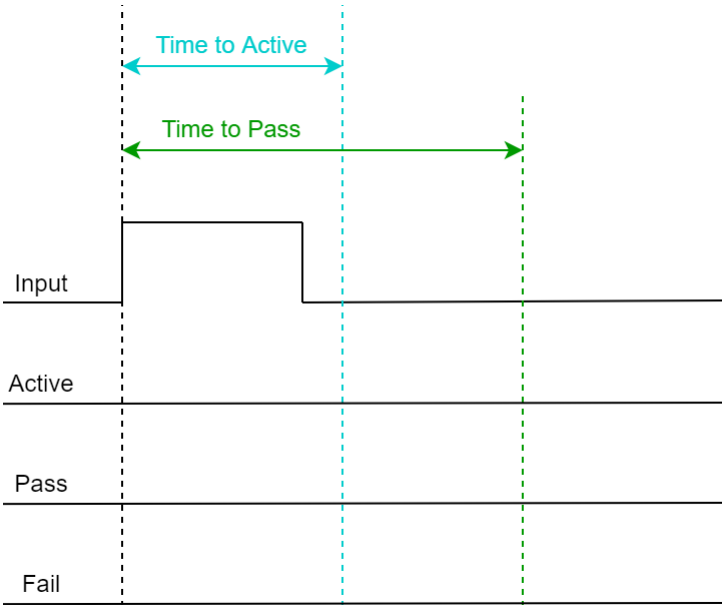
```
class PreTrial:
    def s_MyInput_rise():
        p_State.switch(StartTrial)

class StartTrial:    # StateID = ?
    def s_MyInput_active():
        p_State.switch(ActiveState)

    def s_MyInput_fall():
        p_State.switch(PreTrial)

class ActiveState:    # StateID = ?
    def s_MyInput_pass():
        p_State.switch(PassState)

    def s_MyInput_fail():
        p_State.switch(FailState)
```

Duration Testing

The inputs can use built-in duration testing. In this example, the button has to be pressed for 600ms to get to the 'Active' state, and another 400ms for it to 'Pass'. This timing happens on the hardware and the `active`, `pass` and `fail` slots are triggered in Pynapse.

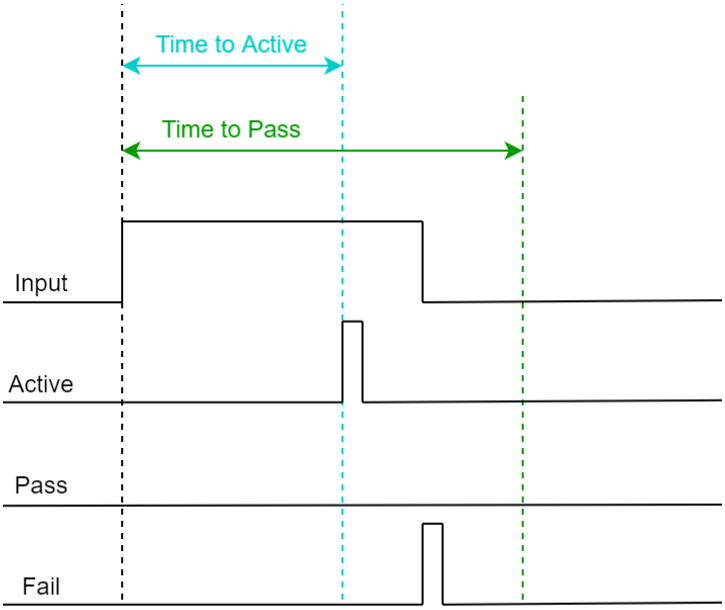
No Trial

Time to Active not reached by Input.
No trial is initiated.



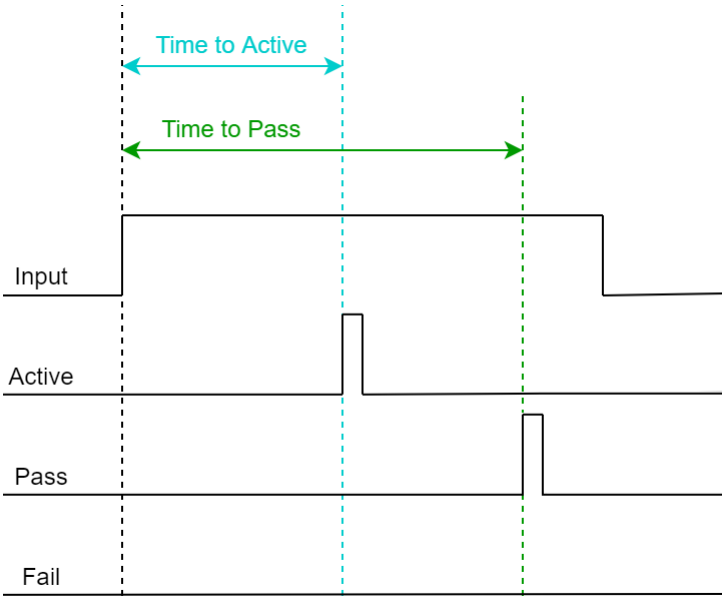
Fail

Time to Active reached by Input, so 'Active' trigger fires.
Time to Pass was not reached by Input, so the 'Fail' trigger fires when Input is released.



Pass

Time to Active reached by Input, so 'Active' trigger fires.
Time to Pass also reached by Input, so 'Pass' trigger fires.



Epoc Storage

Epoc events are triggered on the 'rise' event of the input and a timestamp and value of 3 is stored in the data tank. If the input is true for more than 2 samples then the 'fall' event is also timestamped and stored, with a value of 4.

The full state of the input, including duration test results, is captured in the integer code:

b6	b5	b4	b3	b2	b1	b0
Done	Fail	Pass	Active	Fall	Rise	True

Example values of the epoc event:

Event	Value	Binary Representation
Rise	3	0x0000011
Fall	4	0x0000100
Active	9	0x0001001
Pass	17	0x0010001
Fail	36	0x0100100
Done	64	0x1000000

Buffering

Buffering lets you save a small snippet of data in hardware memory and read it into Pynapse. When the input switches to `true` ('rise' trigger) the buffer is captured. When buffering is finished it fires the `done` trigger.

You can connect the buffer signal source can be any single channel signal in your experiment, including the input signal. Even though the inputs are all converted to digital signals for logic tests, you can still trigger Pynapse to buffer up the original analog signal and then read that into Python for online analysis. For example, you can do a threshold detection on a signal and save the snippet around the threshold crossing, and do something with this in Pynapse.

Example

Display a 1000 sample buffer when triggered.

```
%matplotlib

import matplotlib.pyplot as plt

class Always:   #StateID = 0

    def s_Mode_standby():
        # set up the buffer and plot
        p_Input.MyInput2.setBufferSize(1000)
        p_Input.MyInput2.armBuffer()
        plt.plot()

    def s_MyInput_done():
        # get buffer
        arr = p_Input.MyInput2.getBuffer()

        # plot buffer contents
        plt.plot(arr)
```

Methods

All input methods have the form `p_Input.{INPUT_NAME}.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you.

Buffer operations

Read a triggered snippet of memory from the hardware.

setBufferSize

```
p_Input.MyInput.setBufferSize(npts)
```

Change the number of samples to store in the buffer.

Inputs	Type	Description
npts	integer	Number of samples to buffer

Important

This call must always be made if using a buffer.

Example

Initialize the buffer size before the recording starts.

```
class Always:   #StateID = 0

    def s_Mode_standby():
        # set up the buffer
        p_Input.MyInput.setBufferSize(1000)
        p_Input.MyInput.armBuffer()
```

armBuffer

```
p_Input.MyInput.armBuffer()
```

Let the buffer accept a trigger and fill with new data.

Important

This call must always be made if using a buffer.

Example

Arm the buffer when the experiment first runs.

```
class Always:   #StateID = 0

    def s_Mode_standby():
        # set up the buffer
        p_Input.MyInput.setBufferSize(1000)
        p_Input.MyInput.armBuffer()
```

disarmBuffer

```
p_Input.MyInput.disarmBuffer()
```

Stop the buffer from loading again. Use this to avoid overwriting buffer data before you've had a chance to read it with `getBuffer`.

Example

Prevent the hardware buffer from triggering/ loading new data while you read it.

```
p_Input.MyInput.disarmBuffer()
arr = p_Input.MyInput.getBuffer()
p_Input.MyInput.armBuffer()
```

getBuffer

```
arr = p_Input.MyInput.getBuffer(npts=0, offset=0)
```

Inputs	Type	Description
npts	integer	Number of samples to read (0=all)
offset	integer	Starting index in buffer to read from (0-based)
Returns		
array	number	Buffer contents as python list

Example

Capture the MyInput buffer when the 'done' trigger fires.

```
class Always:   #StateID = 0

    def s_Mode_standby():
        # set up the buffer
        p_Input.MyInput.setBufferSize(1000)
        p_Input.MyInput.armBuffer()

    def s_MyInput_done():
        # get buffer
        arr = p_Input.MyInput.getBuffer()
        print(arr)
```

Duration Settings

setTimingTest

```
p_Input.MyInput.setTimingTest(acttime_sec, passtime_sec)
```

Override the duration test settings applied to the input at runtime.

Inputs	Type	Description
acttime_sec	float	Time to Active, in seconds
passtime_sec	float	Time to Pass, in seconds

Example

Modify the timing tests based on performance.

```
def s_State_enter():
    # if more than 5 successful trials, increase the time to pass by 50 ms.
    if p_Global.success.read() > 5:
        p_Global.pass_time.inc(delta=0.05)
        p_Input.MyInput.setTimingTest(p_Global.act_time.read(), p_Global.pass_time.read())
```

Manual Control

Manual turn inputs on, off, or pulse during runtime. Useful for debugging.

manualOn

```
p_Input.MyInput.manualPulse()
```

Manually turn on the input.

Example

Turn on the input when entering a state.

```
def s_State_enter():
    p_Input.MyInput.manualOn()
```

manualOff

```
p_Input.MyInput.manualPulse()
```

Manually turn off the input.

Example

Turn off the input when exiting a state.

```
def s_State_exit():
    p_Input.MyInput.manualOff()
```

manualPulse

```
p_Input.MyInput.manualPulse()
```

Manually pulse the input.

Example

Pulse the input when entering a state.

```
def s_State_enter():
    p_Input.MyInput.manualPulse()
```

Number Conversion Settings

Override the feature settings applied to the input signal for logic conversion at runtime.

setFeatureThresholds

```
p_Input.MyInput.setFeatureThresholds(thresh_A, thresh_B)
```

Modify the threshold settings for the logic conversion.

Inputs	Type	Description
thresh_A	float	Threshold (in V) for the Thresh-A parameter
thresh_B	float	Threshold (in V) for the Thresh-B parameter

Example

Modify the lever force requirement based on performance.

```
def s_State_enter():
    # if more than 5 successful trials, increase the force required by 0.05
    if p_Global.success.read() > 5:
        p_Global.thresh_A.inc(delta=0.05)
        p_Input.MyInput.setFeatureThresholds(p_Global.thresh_A.read(),
p_Global.thresh_B.read())
```

setScale

```
p_Input.MyInput.setScale(scalefactor)
```

Change the scale factor applied to the signal before it goes through the logic conversion.

Inputs	Type	Description
scalefactor	float	Scale factor applied to signal before logic conversion

Example

Modify the scale factor based on a run-time Control.

```
class Always:   #StateID = 0

    # set input scale factor to value of the SmoothCtrl slider at runtime
    def s_SmoothCtrl_change(value):
        p_Input.MyInput.setScale(value)
```

setSmoothing

```
p_Input.MyInput.setSmoothing(acttime_sec, passtime_sec)
```

Change the smoothing filter applied to the input signal before it goes through the logic conversion.

Inputs	Type	Description
tau_sec	float	Time constant of the low-pass smoothing filter, in seconds (0=off)

Example

Modify the smoothing filter based on a run-time Control.

```
class Always:   #StateID = 0

    # set smoothing 'tau' to value of the TauCtrl slider at runtime
    def s_TauCtrl_change(value):
        p_Input.MyInput.setSmoothing(value)
```

Status

Get information on the current state of the input.

isOn

```
p_Input.MyInput.isOn()
```

Returns true if the input is currently true.

Example

When entering a state, check if an input is already true.

```
def s_state_enter():
    if p_Input.MyInput.isOn():
        print('MyInput is on')
    else:
        print('MyInput is off')
```

isOff

```
p_Input.MyInput.isOff()
```

Returns true if the input is currently false.

Example

When entering a state, check the status of the input.

```
def s_state_enter():
    if p_Input.MyInput.isOff():
        print('MyInput is off')
    else:
        print('MyInput is on')
```

getRawInput

```
p_Input.MyInput.getRawInput()
```

Read the current value of an input. If it is a number, the raw input into the Pynapse gizmo before any feature detection.

Example

When a threshold is crossed, check the current value of the signal.

```
def s_MyInput_rise():
    print(p_Input.MyInput.getRawInput())
```

getStatusBits

```
p_Input.MyInput.getStatusBits()
```

Read the current state of an input as a bitwise integer value. Bit order is:

`Done | Fail | Pass | Active | Fall | Rise | True`

Used by the Pynapse polling loop.

Outputs

You can have up to 8 outputs from the Pynapse gizmo. The outputs can be logic signals that are turned on/off, or triggered for a single sample, or strobed high for a fixed duration. You can also load a custom analog waveform into a buffer and trigger Pynapse to play it out.

Set the **Name** of the output to something that makes sense for your experiment, e.g. 'Reward'. This will be used throughout the Python code and to link to other gizmos.

You can optionally save epoch timestamp events for each output. A timestamp is saved when the output turns on. If the output is high for more than 2 samples then the offset is stored as well.

Triggered - output stays high for a fixed amount of time (controlled by hardware). If **Duration** is 0, this is a single sample.

Strobed - output turns on when the turnOn() method is called and turns off when the turnOff() is called.

See Synchronizing Events for information on the **Sync to State Change** option.

Outputs Tab - Logic Options

General | Inputs | Outputs | Timers | Controls | Globals | Python

Output-1
Output-2
Output-3
Output-4
Output-5
Output-6
Output-7
Output-8

General Options

Name: Output1

Epoc Save: Enable

ID: Out1 Auto ID

Output Type: Logic

Shape

Control Mode: Triggered

Duration: 0.000 secs 0=Single Sample

Sync: to State Change

Parameter Output

Sync: to State Change

Count: 4

	Name	Default Value
1	Par1	0
2	Par2	0
3	Par3	0
4	Par4	0

Outputs Tab - Float Options

General | Inputs | Outputs | Timers | Controls | Globals | Python

Output-1
Output-2
Output-3
Output-4
Output-5
Output-6
Output-7
Output-8

General Options

Name: Output1

Epoc Save: Enable

ID: Out1

Auto ID

Output Type: Float

Shape

Control Mode: Triggered

Duration: 0.000 secs

0 = One Buffer

Sync: to State Change

Output Value: 1.000000

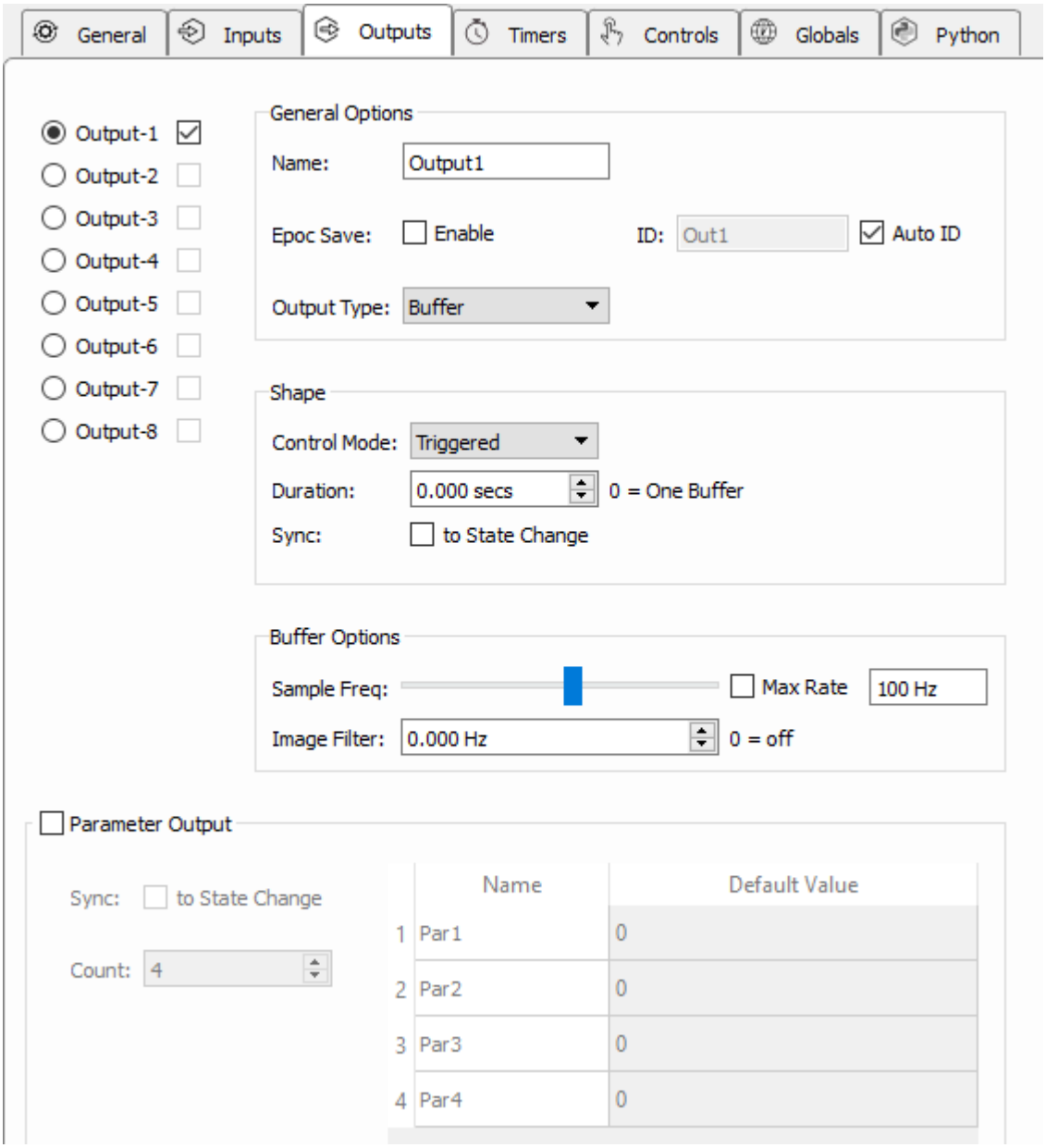
Parameter Output

Sync: to State Change

Count: 4

	Name	Default Value
1	Par1	0
2	Par2	0
3	Par3	0
4	Par4	0

Outputs Tab - Buffer Options



In the Buffer Options, there is an optional low pass filter (**Image Filter**) to remove aliased signals. If unsure, set this to ~⅓ of the output **Sample Freq**.

Buffering

Buffering lets you write a small waveform to hardware memory and trigger it for presentation. This allows you to create fully custom stimuli on the fly, either pre-loaded or adaptive in response to behavioral events.

Parameter Outputs

Pynapse has a set of Parameter outputs which can control all parameters that define a stimulation gizmo. For example, control the waveform parameters of an Audio Stimulation gizmo or an Electrical Stim Driver gizmo directly from Pynapse, just like you would use a Parameter Sequencer gizmo for. Create the parameters on the fly based on subject feedback, or play from a python-generated list. See Parameter Methods below.

See Synchronizing Events for information on the **Sync to State Change** option.

See Using Parameters for more general information on parameters.

Output Methods

All output methods have the form `p_Output.{OUTPUT_NAME}.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you. 'Output1' is the default name of the first output. The name of each method gets replaced with the name of your actual output, so if you name the output 'Reward' then `p_Output.Reward.fire()` is an available method.

Manual Control

Manual turn outputs on, off, or fires a pulse waveform during runtime. Useful for stimulus/reward presentation.

fire

```
p_Output.MyOutput.fire()
```

Quickly pulse the output. If **Duration** is non-zero, the output will stay high for that set duration. Set **Duration** to zero to use this output to trigger other gizmos, e.g. trigger an Audio Stimulation gizmo. If **Output Type** is **Buffer**, this will play the output buffer one time.

Example

Trigger an output when the input goes high.

```
class Always:   #StateID = 0

    def s_MyInput_pass():
        p_Output.MyOutput.fire()
```

turnOn

```
p_Output.MyOutput.turnOn()
```

Turn the output on indefinitely. If the output is a buffer, it will continuously loop until turned off

Example

Link an input status to an output.

```
class Always:   #StateID = 0

    def s_MyInput_rise():
        p_Output.MyOutput.turnOn()

    def s_MyInput_fall():
        p_Output.MyOutput.turnOff()
```

turnOff

```
p_Output.MyOutput.turnOff()
```

Turn the output off.

Example

Link an input status to an output.

```
class Always:   #StateID = 0

    def s_MyInput_rise():
        p_Output.MyOutput.turnOn()

    def s_MyInput_fall():
        p_Output.MyOutput.turnOff()
```

Duration Settings

setPulseShape

```
p_Output.MyOutput.setPulseShape(dur_sec, outval=None)
```

Override the output **Duration** (if **Control Mode** is set to **Triggered**) and the **Output Value** settings (if **Output Type** is set to **Float** or **Integer**) at runtime.

Inputs	Type	Description
dur_sec	float	Duration of the output pulse when triggered with `fire`, in seconds
outval	float or integer	Output value when true

Example

Modify the pulse shape and output value based on performance.

```
def s_State_enter():
    # if more than 5 successful trials, decrease the output pulse time by 50 ms and output
value by 1.
    if p_Global.success.read() > 5:
        p_Global.pulse_dur.dec(delta=0.05)
        p_Global.output_val.dec(delta=1)
        p_Output.MyOutput.setPulseShape(p_Global.pulse_dur.read(), p_Global.output_val.read())
```

Buffer operations

Load a list of values into a memory buffer on the hardware and trigger playback.

setBuffer

```
p_Output.MyOutput.setBuffer(wave)
```

Loads a python list or NumPy array into an output buffer. Call `fire` to play the output buffer once. Call `turnOn` to play buffer on a loop until calling `turnOff`. Supports up to 100,000 samples.

Inputs	Type	Description
wave	list	List of numbers to load into output buffer

Example

Load an output buffer with 1,000 random numbers before the recording starts, and trigger it when MyInput goes true.

```
import numpy as np

class Always:   #StateID = 0

    def s_Mode_standby():
        import random
        p_Output.MyOutput.setBuffer(np.random.random(1000).tolist())

    def s_MyInput_rise():
        p_Output.MyOutput.fire()
```

Status

Get information on the current state of the output.

isOn

```
p_Output.MyOutput.isOn()
```

Returns true if the output is currently true.

Example

When entering a state, check if an output is already true.

```
def s_state_enter():
    if p_Output.MyOutput.isOn():
        print('MyOutput is on')
    else:
        print('MyOutput is off')
```

isOff

```
p_Output.MyOutput.isOff()
```

Returns true if the output is currently false.

Example

When entering a state, check the status of the output.

```
def s_state_enter():
    if p_Output.MyOutput.isOff():
        print('MyOutput is off')
    else:
        print('MyOutput is on')
```

Parameter Methods

All parameter methods have the form `p_Param.{PARAMETER_NAME}_write`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you. 'Par1' is the default name of the first parameter. The name of each `write` method gets replaced with the name of your actual parameter, so if the parameter is called 'Freq' then `p_Param.Freq_write(val)` is an available method.

Par1_write

```
p_Param.Par1_write(val)
```

Write a new value for this parameter.

Inputs	Type	Description
val	float	Floating point value to send to this parameter output

Example

Modify the wave frequency for an Audio Stimulation gizmo when a state changes.

```
class PrepStim:   #StateID = 0
    def s_State_enter():
        # get next stim ready
        wave_freq = 1000
        p_Param.p_Param.WaveFreq_write(wave_freq)
```

List_write

```
p_Param.List_write(vlist)
```

Write all the parameters at once using a list.

Inputs	Type	Description
vlist	list	List of floating point numbers to send to all parameter outputs

Example

Prepare a list of stimulation parameters for an Audio Stimulation gizmo when a state changes.

```
class PrepStim:   #StateID = 0
    def s_State_enter():
        # get next stim ready
        pulse_count = 3
        pulse_period = 100
        wave_freq = 1000
        p_Param.List_write([pulse_count, pulse_period, wave_freq)
```

States

Pynapse has an internal state machine that logs all events and keeps track of the current state. New triggers coming in are filtered through this state machine, so that only the slot methods associated with the current state can run.

There is a special 'Always' state - slot methods in the Always state can trigger on any polling loop. This is a useful state to add user mode controls (start/pause/stop).

States are 'classes' in the Python code that have the special comment `#StateID = ?` at the end of the class definition. The number defined here is the id number associated with this state. This value will be timestamped and stored with the data in the data tank. If the parser finds a `?`, it will automatically assign a number for you. Otherwise enter an integer to lock the StateID in place, for example `#StateID = 555`.

See Working with StateIDs for more information.

Slot Methods for Responding to State Changes

These state slots capture state machine changes. They are available as method definitions inside Pynapse states, including the Always state. Write a method with this name to react to the corresponding event.

Slot name	Event
s_State_change	Triggers on any state change
s_State_enter	Triggers once when the state begins
s_State_exit	Triggers once when the state ends
s_State_timeout	Triggers when the state timeout is reached

Example

Turn on an output only while in a particular state.

```
class StartTrial:    # StateID = ?
    # turn on MyOutput when entering state
    def s_State_enter():
        p_Output.MyOutput.turnOn()

    # when MyInput passes 'Time to Active', switch to ActiveState
    def s_MyInput_active():
        p_State.switch(ActiveState)

    # turn off MyOutput when exiting state
    def s_State_exit():
        p_Output.MyOutput.turnOff()

class ActiveState:    # StateID = ?
    # when MyInput passes 'Time to Pass', switch to PassState
    def s_MyInput_pass():
        p_State.switch('PassState')

    def s_MyInput1_fail():
        p_State.switch(FailState)
```

In this example, use s_State_change() to track order of state execution. Suppose there are many states that exit to TargetState. If the state that exited to TargetState is TargetOldState, we want to do something.

```
class Always:    # StateID = 0
    def s_State_change(newstateidx, oldstateidx):
        print('new state', newstateidx, 'old state', oldstateidx)
        if newstateidx == TargetState and oldstateidx == TargetOldState:
            print('do something')
```

State Timeouts

The Pynapse state machine has a built-in Timer that is used as a timeout within the current state that moves to another state if it fires. Timeouts are usually set in the s_State_enter() slot method but can be set anywhere in the State. Timeouts can also be canceled.

Example

If the user fails to press a button (MyInput) within five seconds, we want to move to a NoTrial state and wait there for ten seconds before starting a new trial.

```
class StartTrial:    # StateID = ?

    # if no input is received after 5 seconds, switch to NoTrial state
    def s_State_enter():
        p_State.setTimeout(5, NoTrial)

    def s_MyInput_rise():
        p_State.switch(TrialState)

class NoTrial:    # StateID = ?
    # wait 10 seconds, return to StartTrial
    def s_State_enter():
        p_State.setTimeout(10, StartTrial)

class TrialState:    # StateID = ?
    # turn on an output
    def s_State_enter():
        p_Output.MyOutput.turnOn()
```

Methods

All state methods have the form `p_State.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you.

State Control

switch

```
p_State.switch(newstate)
```

Tell Pynapse to move to a new state. All states are python 'classes'. The input to `switch` can be either the class or the string class name you want to switch to. See the example below

Inputs	Type	Description
newstate	class or string	Name of new class to switch to

Note

The function that contains the `switch` command does not exit immediately after switching the internal state. This can have unintended consequences, particularly if you are using the **Sync to State Change** option for outputs or timers. Best practice is to use the `switch` command last, right before the function exits.

See Synchronizing Events for information.

Example

Switch between states when MyInput goes high.

```
class StartTrial:    # StateID = ?

    def s_MyInput_active():
        p_State.switch(ActiveState)

class ActiveState:    # StateID = ?
    def s_MyInput_pass():
        # you can also switch states with a string name
        p_State.switch('PassState')

    def s_MyInput_fail():
        p_State.switch(FailState)
```

setTimeout

```
p_State.setTimeout(secs, stateOnTimeout)
```

Switch to a default state after a certain period of time.

Inputs	Type	Description
secs	float	Timeout duration in seconds
stateOnTimeout	class or string	New of the class to switch to

Important

There can only be one active timeout per state. If you need to set a new timeout within the state, use the cancelTimeout method first.

Example

Toggle between the FirstState and SecondState until MyInput rises in FirstState.

```
class FirstState:    # StateID = ?

    # if no input is received in 5 seconds, switch to SecondState
    def s_State_enter():
        p_State.setTimeout(5, SecondState)

    def s_MyInput_rise():
        p_State.switch(EndState)

class SecondState:    # StateID = ?

    # wait 5 seconds, return to FirstState
    def s_State_enter():
        p_State.setTimeout(5, FirstState)

class EndState:    # StateID = ?
    def s_State_enter():
        print('done')
```

cancelTimeout

```
p_State.cancelTimeout()
```

Cancel the current timeout. Can be called anywhere within the state.

Example

Give the subject 15 seconds to press MyInput 10 times. If successful, cancel the state timeout and give the subject unlimited time to reach 20 presses before moving to the success state.

```
class TrialState:    # StateID = ?
    def s_State_enter():
        # reset counter
        p_Global.count.write(0)

        # if target isn't reached in 15 seconds switch to DefaultState
        p_State.setTimeout(15, DefaultState)

    def s_MyInput_rise():
        # increment counter
        p_Global.count.inc()

        # if we reached our first target, cancel timeout
        if p_Global.count.read() == 10:
            p_State.cancelTimeout()
        elif p_Global.count.read() == 20:
            p_State.switch(SuccessState)

class DefaultState:    # StateID = ?
    def s_State_enter():
        print('default')

class SuccessState:    # StateID = ?
    def s_State_enter():
        print('success')
```

Status

isCurrent

```
p_State.isCurrent(stname)
```

Check if the current state is the given name. This is useful if you have a lot of States defined but want to do similar actions in multiple states for a given slot method. You can move the logic into the Always state and avoid repeating yourself. See the example below.

Or if you want to

Inputs	Type	Description
stname	class or string	Name of state to check

Example

In a long list of states, we want to turn the MyOutput on in just two of them.

```
class Always:   #StateID = 0
    def s_MyInput1_rise():
        if p_State.isCurrent(State8) or p_State.isCurrent(State20):
            p_Output.MyOutput.turnOn()
```

In this second example, the target state is dynamically set by a global variable. When MyInput2 turns on, the slot method is captured in the Always state and only continues (turns on Output2) if the current state matches the target state. This target state can be set on the user interface or somewhere else in the code using the Globals asset. This could also be tied to a Control asset.

```
    class Always:   #StateID = 0
        def s_MyInput2_rise():
            if p_State.isCurrent(p_Global.target_state.read()):
                print('current state is the target state set in the user interface')
                p_Output.MyOutput2.turnOn()
```

isNotCurrent

```
p_State.isNotCurrent(stname)
```

Check if the current state is not given name. This is useful if you have a lot of States defined but don't want to include the same identical slot method in all of them except a small number of states. You can include this logic check within the Always state. See the example below.

Inputs	Type	Description
stname	class or string	Name of state to check

Example

When MyInput turns on, turn on MyOutput in all states unless we're in the DontStim state.

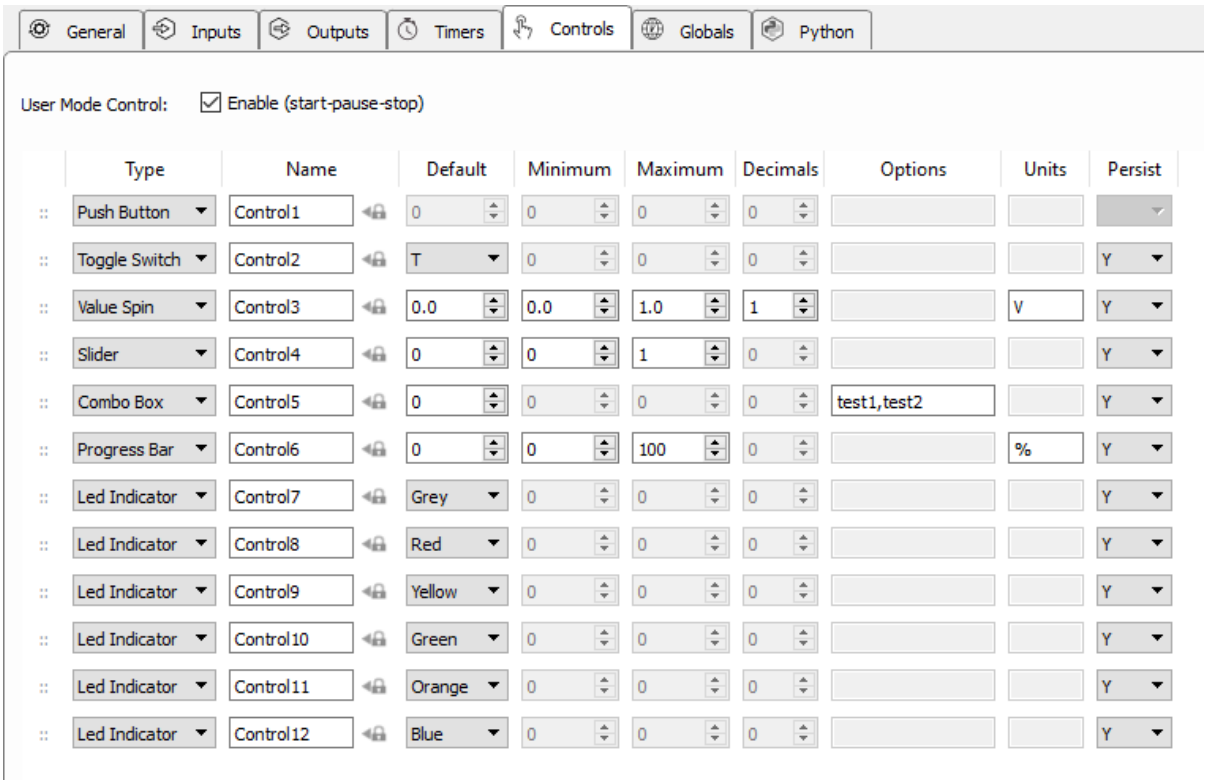
```
class Always:   #StateID = 0
    def s_MyInput_rise():
        if p_State.isNotCurrent(DontStim):
            p_Output.MyOutput.turnOn()
```

Controls

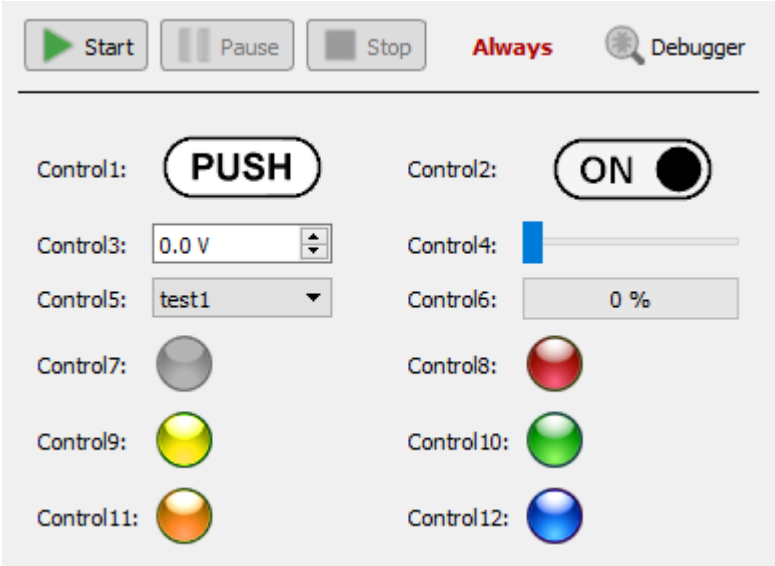
You can create run-time widgets of all different kinds and read/ write the values of the widget. Controls will issue a trigger when their value is changed, which can be captured and reacted to in the Pynapse event loop. You can also read the value of the controls inside any method.

You can add up to 12 custom controls. All available controls and their options are shown in the images below. Drag and drop the control rows in design-time to change the order they are displayed at runtime.

User Mode Controls let you start, pause, resume, or stop the state flow in Pynapse during runtime. User mode controls are enabled by the check box in the Controls tab. See Slot Methods for Responding to Control Changes for an example of how these might be used.



Controls Tab



Runtime Tab

Slot Methods for Responding to Control Changes

These control slot methods capture status information about the controls. They are available as method definitions inside Pynapse states for each input. Write a method with this name to react to the corresponding event.

Slot name	Event
s_Umode_start	Start button pressed
s_Umode_pause	Pause button pressed
s_Umode_resume	Resume button pressed
s_Umode_stop	Stop button pressed
s_MyControl_change	MyControl value changed

All custom control slot methods `s_{CONTROL_NAME}_change`. Type `def s_` in the Pynapse Code Editor and let the code completion do the work for you.

Example

Switch to a starting state when user clicks the 'Start' button on the Pynapse tab at runtime.

```
class Always:    # StateID = 0
    def s_Umode_start():
        p_Global.count.write(0)
        p_State.switch(PreTrial)

    def s_Umode_pause():
        p_Global.count.write(0)
        p_State.switch(Resting)

    def s_Umode_resume():
        p_State.switch(PreTrial)

    def s_Umode_stop():
        print(p_Global.ntrials.read(), 'trials completed')
        p_State.switch(EndTrials)

    # capture any control value change with this
    def s_MyControl_change(value):
        print('new control value', value)
```

Methods

All control methods have the form `p_Control.{CONTROL_NAME}.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you.

Status

read

```
value = p_Control.MyControl.read()
```

Read the current value of the control. For combo box controls, the value is the index into the list of items in the combo box.

Example

Set the next stimulation based on a slider value controlled by the user at runtime.

```
class PrepStim:   #StateID = 0
    def s_State_enter():
        # get next stim ready
        wave_freq = p_Control.MyControl.read()
        p_Param.p_Param.WaveFreq_write(wave_freq)
```

Control

write

```
p_Control.MyControl.write(val)
```

Write a new value to the control. For combo box controls, the value is the index into the list of items in the combo box.

Inputs	Type	Description
val	number	New value of the control

Example

Increment a progress bar.

```
class EndTrial:   #StateID = 0
    def s_State_enter():

        # increment completed trials counter
        p_Global.completed_trials.inc()

        # update progress bar
        progress = 100 * p_Global.completed_trials.read() / p_Global.desired_trials.read()
        p_Control.MyProgressBar.write(progress)
```

setRange

```
p_Control.MyControl.setRange(minv, maxv)
```

Set the value range of the control between minv and maxv.

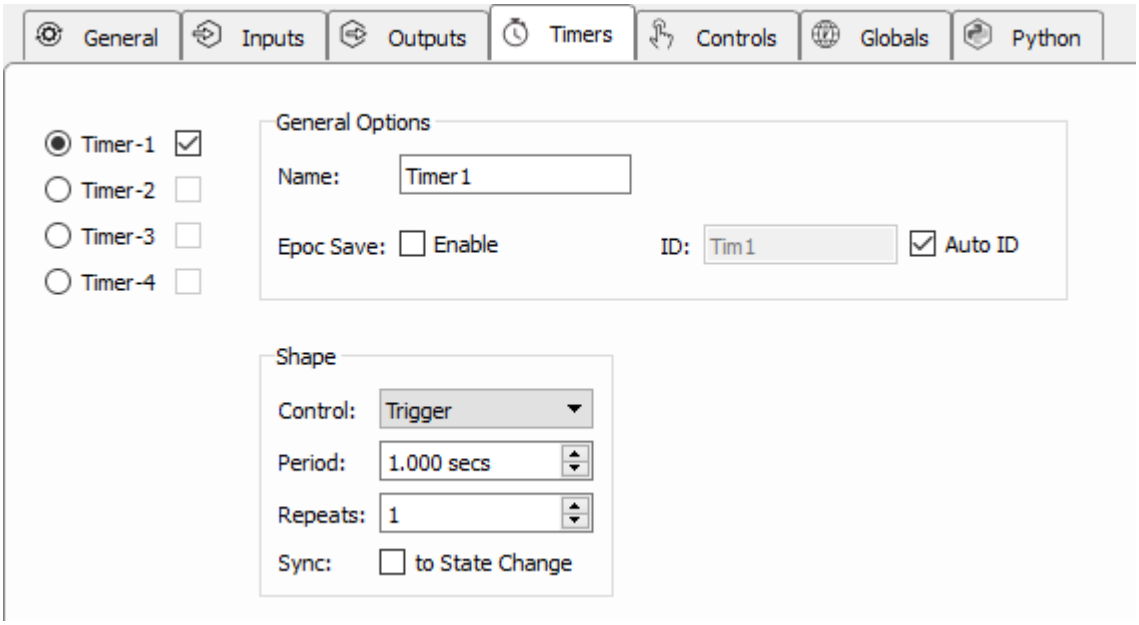
Inputs	Type	Description
minv	number	New minimum value for this control
maxv	number	New maximum value for this control

Timers

Timers can be used independent of states to control program flow or stimulus presentation.

The period and number of repeats can be modified at runtime within the Python code.

If **Control** type is 'Trigger', then you initiate the timer with the `start` method and it runs until it has reached the number of repeats. In 'Enable' mode, you turn on the timer and can optionally turn it off prematurely with the `turnOn` / `turnOff` method pairs.



Timers Tab

See Synchronizing Events for information on the **Sync to State Change** option.

Slot Methods for Responding to Timer Ticks

These slot methods capture status information about the timers. They are available as method definitions inside Pynapse states for each timer. Write a method with this name to react to the corresponding event.

Slot name	Event
s_MyTimer1_tick	Fires on each tick of `MyTimer1`. Note: this event does not fire when the timer is first turned on (count = 0)

The timer slot method has the form `s_{TIMER_NAME}_tick`. Type `def s_` in the Pynapse Code Editor and let the code completion do the work for you.

Example

Set a timer once a second for 10 seconds, and print the current timer count when it fires

```
class Always:    # StateID = 0
    def s_Mode_standby():
        p_Timer.MyTimer.setPeriod(1)
        p_Timer.MyTimer.setRepeats(10)

    def s_Mode_recprev():
        p_Timer.MyTimer.turnOn()

    def s_Timer1_tick(count):
        print(count)
```

In this example, Synapse stops the recording after 10 seconds and switches to Idle.

```
class Always:    # StateID = 0
    def s_Mode_standby():
        p_Timer.MyTimer.setPeriod(10)
        p_Timer.MyTimer.setRepeats(1)

    def s_Mode_recprev():
        p_Timer.MyTimer.turnOn()

    def s_Timer1_tick(count):
        print('done')
        syn.setModeStr('Idle')
```

Methods

All control methods have the form `p_Timer.{TIMER_NAME}.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you.

Setup

setPeriod

```
p_Timer.MyTimer.setPeriod(period_sec)
```

Set the period between timer ticks.

Inputs	Type	Description
period_sec	number	New period, in seconds

setRepeats

```
p_Timer.MyTimer.setRepeats(reps)
```

Set the number of ticks before the timer finishes.

Inputs	Type	Description
reps	number	Number of times to repeat the timer tick

Control

turnOn

```
p_Timer.MyTimer.turnOn()
```

Start a timer that has **Control** mode set to 'Enable'. This call is required to start any timer in 'Enable' mode.

turnOff

```
p_Timer.MyTimer.turnOff()
```

Stop a timer prematurely. This only works with timers that have **Control** mode set to 'Enable'.

start

```
p_Timer.MyTimer.start()
```

Start a timer that has **Control** mode set to 'Trigger'. This call is required to start any timer in 'Trigger' mode.

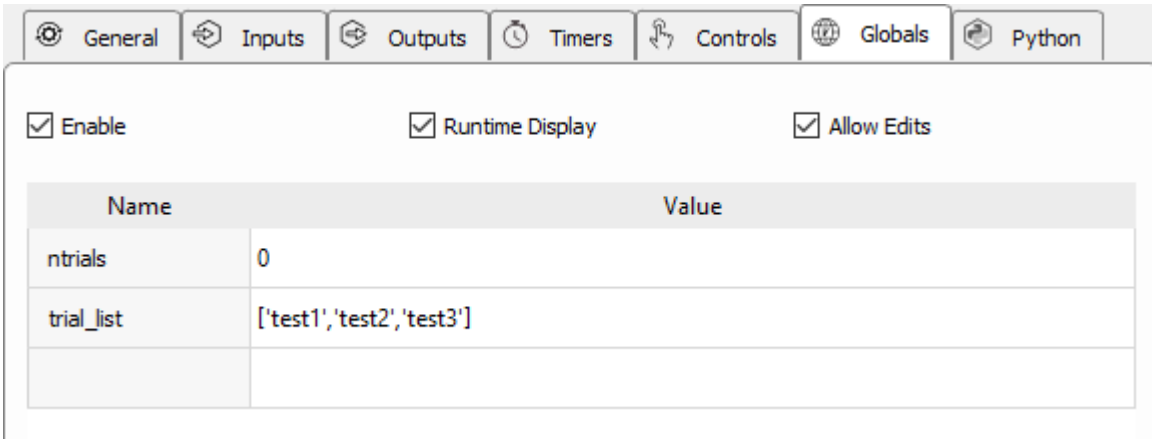
Globals

Globals are global variables you can read/write in your Python logic code. They can also be added to the runtime interface for visual display, and can also be editing at runtime.

The variable can be any python object. It's string representation will be displayed in the runtime UI.

This is equivalent to using the `global` keyword in Python, except by storing it as a Pynapse asset instead you don't have to remember the `global` keyword everywhere you want to modify it, and you also get a runtime interface to see/ edit the current value.

Give each variable a name and a default value in the Globals Tab.



Globals Tab

When **Runtime Display** is enabled, the same global variables interface is shown in the Pynapse tab at runtime.

When **Allow Edits** is enabled, at runtime you can double-click on a variable and change its value in the dialog.

> **Note**
>
> Editing the variable using the runtime display may changes its data type. After editing, the variable will be an int, float, str, or list.

Methods

All globals methods have the form `p_Global.{GLOBAL_NAME}.{METHOD}`. Type `p_` in the Pynapse Code Editor and let the code completion do the work for you.

Status

read

```
value = p_Global.varname.read()
```

Read the current value of a global variable. For combo box controls, the value is the index into the list of items in the combo box (zero-based).

Control

write

```
p_Global.varname.write(v)
```

Write a new value to the global variable. This can be any python object.

Inputs	Type	Description
v	python object	New value assigned to global variable

inc

```
p_Global.varname.inc(delta=1)
```

Increment the global variable value.

Inputs	Type	Description
delta	number	Amount to increase variable value (default=1)

dec

```
p_Global.varname.dec(delta=1)
```

Decrement the global variable value.

Inputs	Type	Description
delta	number	Amount to decrease variable value (default=1)

Data Conversion

toFloat

```
p_Global.varname.toFloat()
```

Convert the variable value to a floating point number for math operations

toInt

```
p_Global.varname.toInt()
```

Convert the variable value to an integer number for math operations

toString

```
p_Global.varname.toFloat()
```

Convert the variable value to a string.

toPretty

```
p_Global.varname.toFloat()
```

Convert the variable to a string containing its name and value. Useful for logging

Example

```
p_Global.varname.write(1)

# prints 'varname=1'
print(p_Global.varname.toPretty())
```

Synapse Control

Pynapse has built in slots for Synapse mode change events. These are useful in the 'Always' state to initialize variables or buffers for stimulation before the recording begins.

Slot Methods for Responding to Synapse Mode Changes

These slots capture Synapse system mode change events. They are available as method definitions inside Pynapse states. Write a method with this name to react to the corresponding mode change event.

Slot name	Event
s_Mode_change(newmode)	Triggers on any mode change
s_Mode_idle	Mode changed to idle
s_Mode_standby	Mode changed to standby
s_Mode_preview	Mode changed to preview
s_Mode_record	Mode changed to record
s_Mode_recprev	Mode changed to preview or record

Important

If you use `p_State.switch()` inside `s_Mode_standby()`, this overrides the 'Initial State' setting on the General Tab.

Example

Preload a stimulus output buffer before the experiment runs

```
import numpy as np

class Always:   #StateID = 0
    def s_Mode_standby():
        import random
        p_Output.MyOutput.setBuffer(np.random.random(1000).tolist())
```

When experiment starts, switch to PreTrial state as the default starting state.

```
class Always:   #StateID = 0
    def s_Mode_standby():
        p_State.switch(PreTrial)
```

SynapseAPI

Pynapse also exposes an instance of the SynapseAPI class as the variable `syn` in the source code editor. Type `syn.` in the Code Editor and code completion shows you all of the available method calls. For the complete list of SynapseAPI methods and how to use them, see SynapseAPI Manual.

Important

SynapseAPI calls goes through sockets, and that adds some extra delay. The SynapseAPI calls are also affected by what is happening in the Synapse window. For example, if you do something that is graphically intensive such as resizing the windows during a recording, you can see a big (>100ms) lag before the call gets through. It shouldn't be relied on for time critical events.

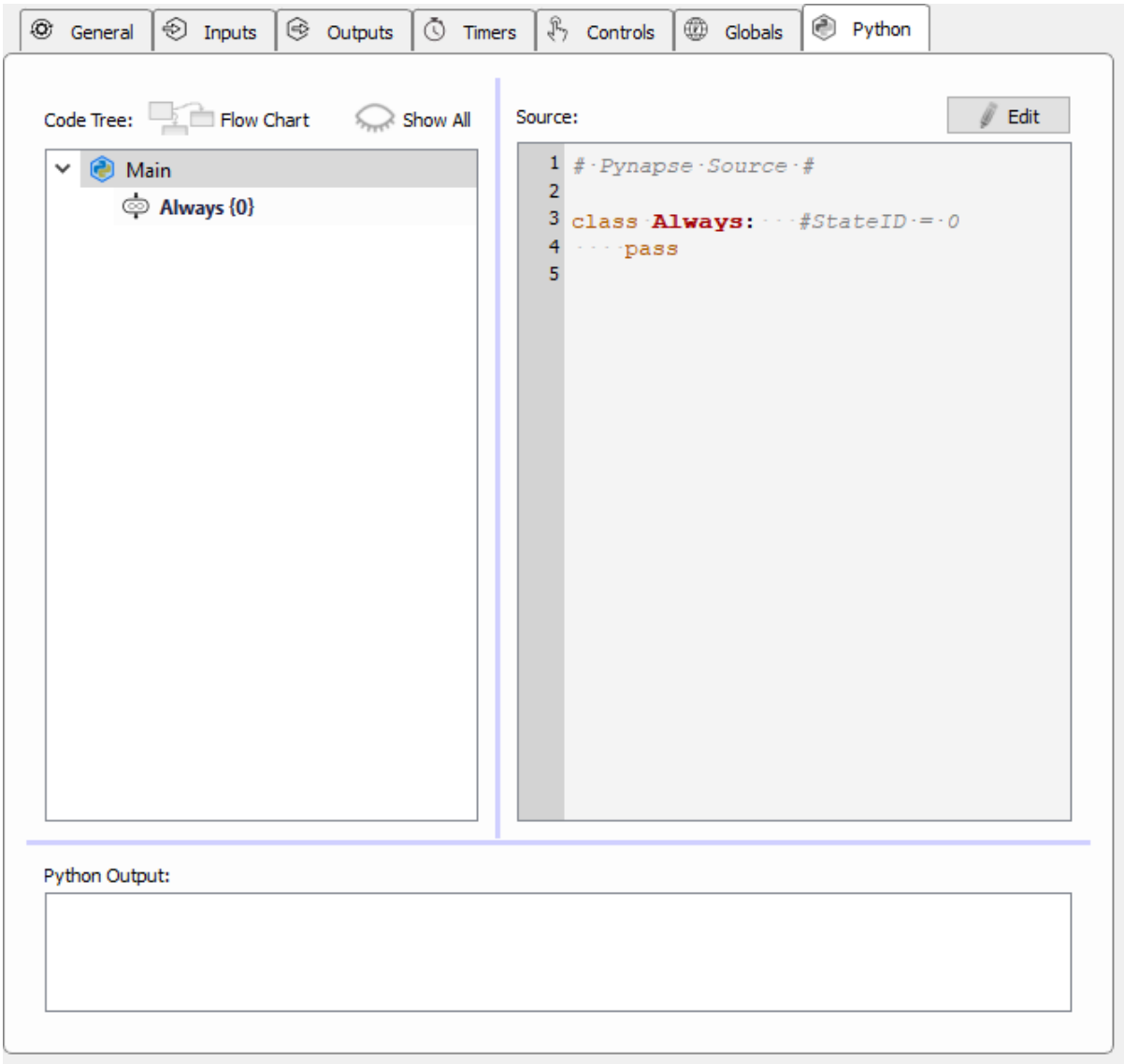
Example

User puts system into Standby mode, then when trigger is received Pynapse switches system to Record mode.

```
class Always:   #StateID = 0
    def s_MyInput_rise():
        syn.setModeStr('Record')
```

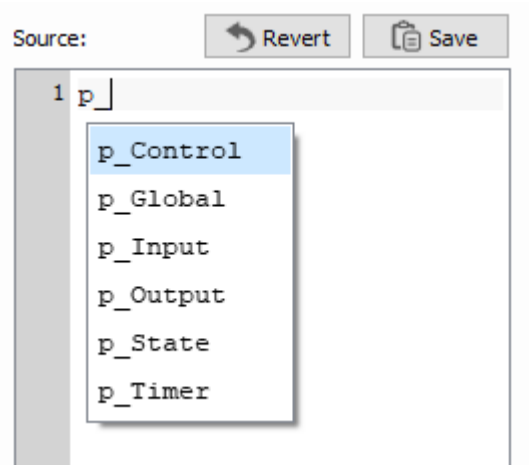
Code Editor and Parser

The built-in Python editor is where all your states and events are defined, telling the Pynapse event loop what do when events happen. Click the 'Edit' button, or double-click on the Source code, to enable editing.

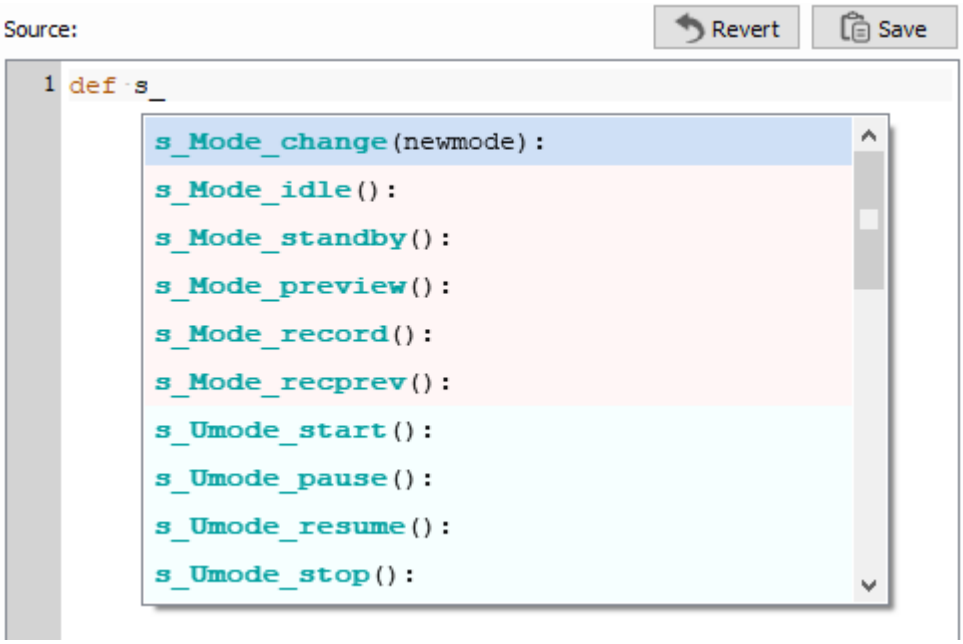


The built-in Python editor does code completion for you. Every time you press 'Commit' the parser dynamically generates a list of methods and event triggers you have access to based on the named inputs, outputs, controls, globals, and timers. All Pynapse assets start with `p_` and all slot methods start with `def s_`, so start there and the code completion will show you the available assets or slots.

Assets Code Completion



Slots Code Completion



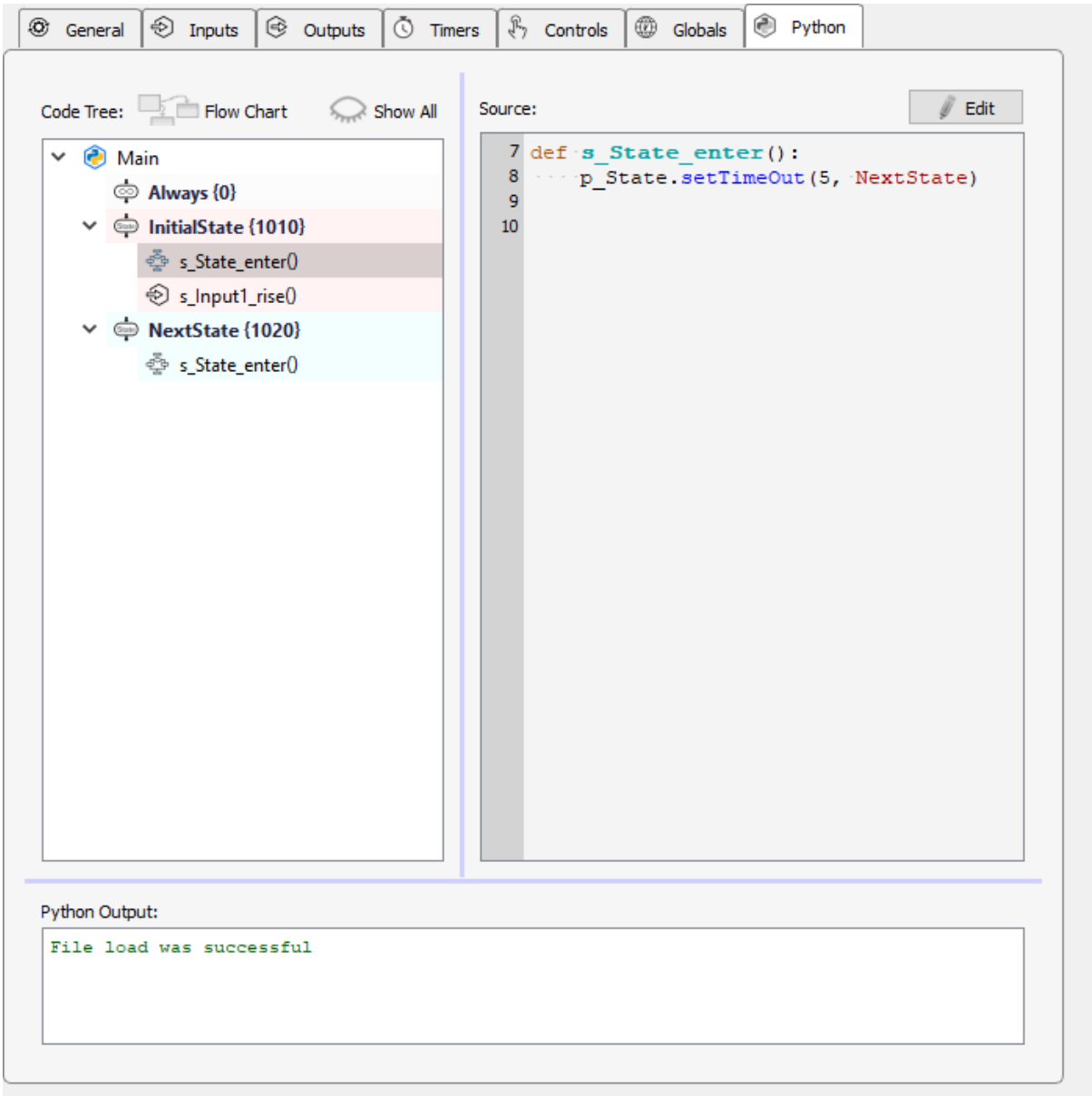
You can also right-click → "Help" on anything in the editor to show more complete documentation on the object under the cursor.

Asset names are linked to their method calls in the Python code. Assets that appear in the Python code will have a lock icon next to their names in their asset tab. If you decide to change the name of an asset after writing Python code that interacts with it, click the lock icon to change the name of the asset and update all of the instances of this name in the Python code.

Code Tree

The parser identifies all of the states and all of the methods that are written within the states that respond to events, and builds the Code Tree.

You can click on any item in the Code Tree and the Editor shows you just the selected state or methods so you are just editing that part of the code. If you want to look at the entire file, click 'Main' in the Code Tree.

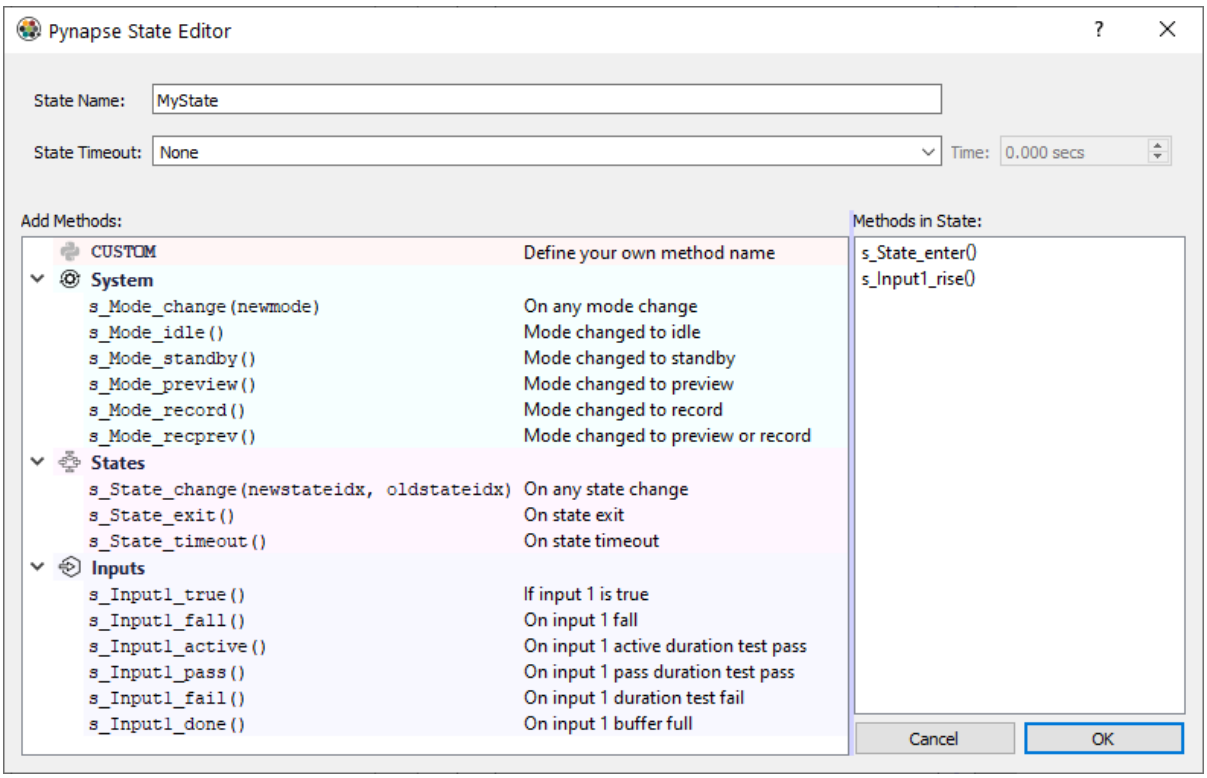


Note

By default the Code Tree shows only Pynapse states and slot methods. Sometimes you'll write methods inside states that aren't Pynapse slots. The 'Show All' button will include these methods in the Code Tree.

To Add a State

The easiest way to add a state is by right-clicking on an existing state in the Code Tree (or 'Main') and adding a state from the menu. This brings up a state creation wizard that shows you all the available hardware events you can capture with the state. You choose which methods to include in the code and a state timeout if desired. This saves you from having to remember the exact syntax for creating a state every time.



You can also edit the Python code directly with the required state structure:

```
class MyNewState:  #StateID = ?
    pass
```

> **Note**
>
> After you create a state, you can get back to the creation wizard by right-clicking the state name in the Code Tree → Reconfigure.

Working with StateIDs

Classes defined with the `#StateID = ?` comment are parsed as Pynapse states. If the StateID is `?` then Pynapse will automatically assign a number to the state for you. The StateIDs are shown next to the state name in the Code Tree.

> **Note**
>
> You can include regular classes in the code that aren't Pynapse states by excluding the `#StateID` comment from the class definition.

The StateID number is saved into the data tank when state changes occur during runtime. It is important that the StateIDs are consistent across recordings. If you make changes to your Pynapse source code and all of the StateIDs are `?` then these numbers will change if you add or remove states from your source code. This will make it harder to organize your data during post-processing if you are trying to compare data made with your newer experiment to recordings made with earlier versions of your experiment.

The solution is to lock the StateIDs to a value right in the comment, like `#StateID = 555`. If you already have code written with automatically generated StateIDs, you can lock the current StateIDs in place by right-clicking on 'Main' and select 'Commit State IDs'. This will overwrite all of the `#StateID = ?` comments with their assigned StateID, like `#StateID = 1010`.

Important

StateIDs have to be defined in order (top to bottom) in the Python source code. For example, this code is invalid because the state class defined with `#StateID = 2` is before `#StateID = 1`.

```
class Always: #StateID = 0
    def s_Mode_standby():
        p_State.switch(MyState1)

class MyState1: #StateID = 2
    def s_State_enter():
        print('MyState1')
        p_State.setTimeout(1, MyState2)

class MyState2: #StateID = 1
    def s_State_enter():
        print('MyState2')
        p_State.setTimeout(1, MyState1)
```

Flow Chart

As experiments get more complicated, it is helpful to see an overview of how the states, inputs, and outputs are connected. Click the Flow Chart button to see a graphical representation of all these links. Double-click on a state in the Flow Chart to show it in the code editor.

Organizing Your Code

There are two kinds of files: Pynapse files and Python files.

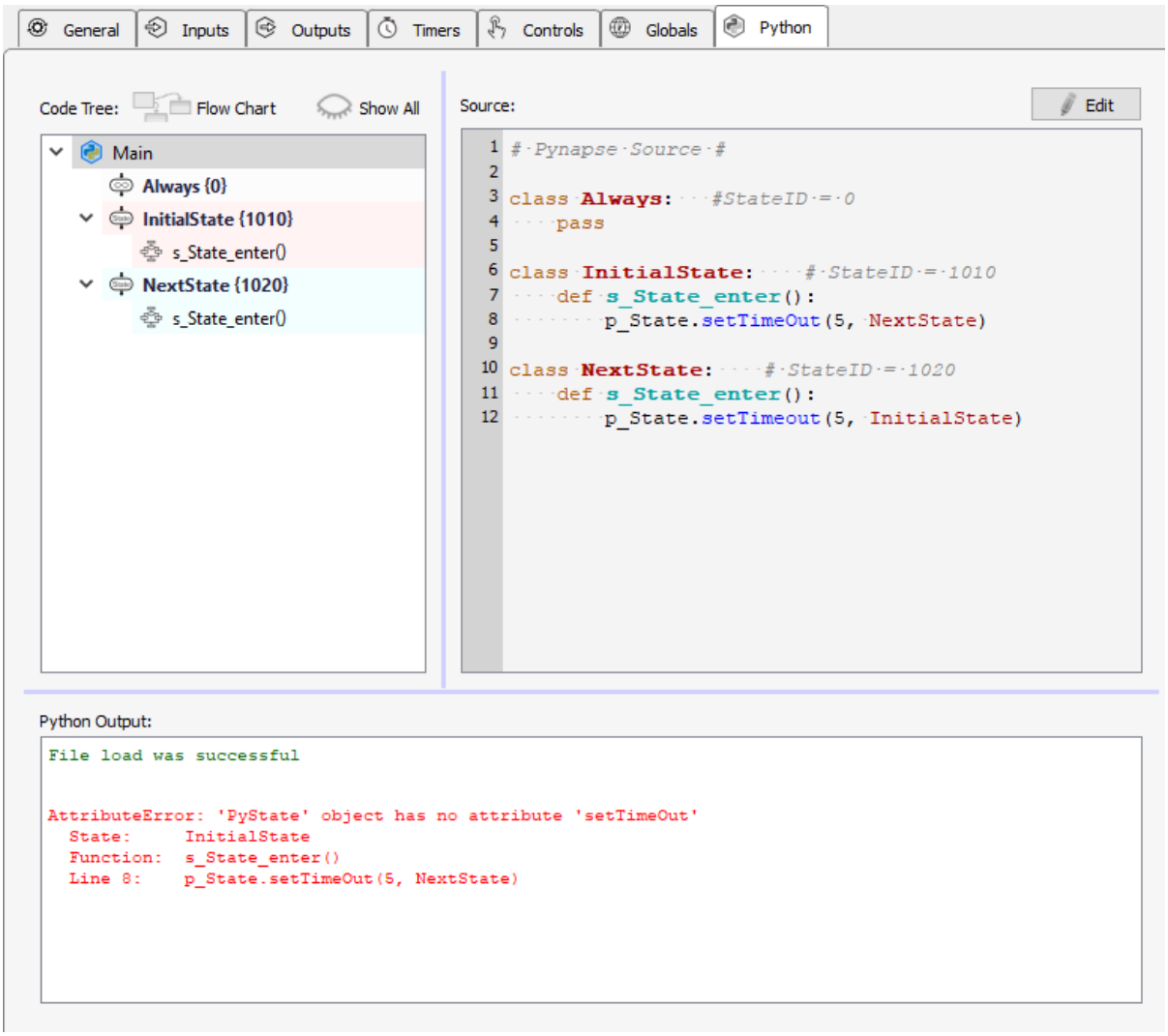
'Main' is the default block of Pynapse code in the Code Tree. You can have up to three other 'Local' Pynapse code blocks that are also saved in the experiment. These are not files on disk but rather saved with the experiment in the Synapse database. Right-click on 'Main' in the Code Tree → Add Local Pynapse Block. You can import/export them if desired.

If you want to have your own classes/modules outside of Synapse you can also link to them from the experiment. This way you can share common files across experiments. You can link to as many existing files on disk as you want and they get imported automatically. In the Code Tree, right-click on 'Main' → Add Python Import File, and choose the Python file.

Testing

You can right-click on any state, method, or Python file in the Code Tree and select 'Test'. This will load the source file and run every method inside of it. Any obvious errors that will come up at run-time (like naming problems) are shown in the Python Output window at the bottom, with a reference to the method and line number causing the error.

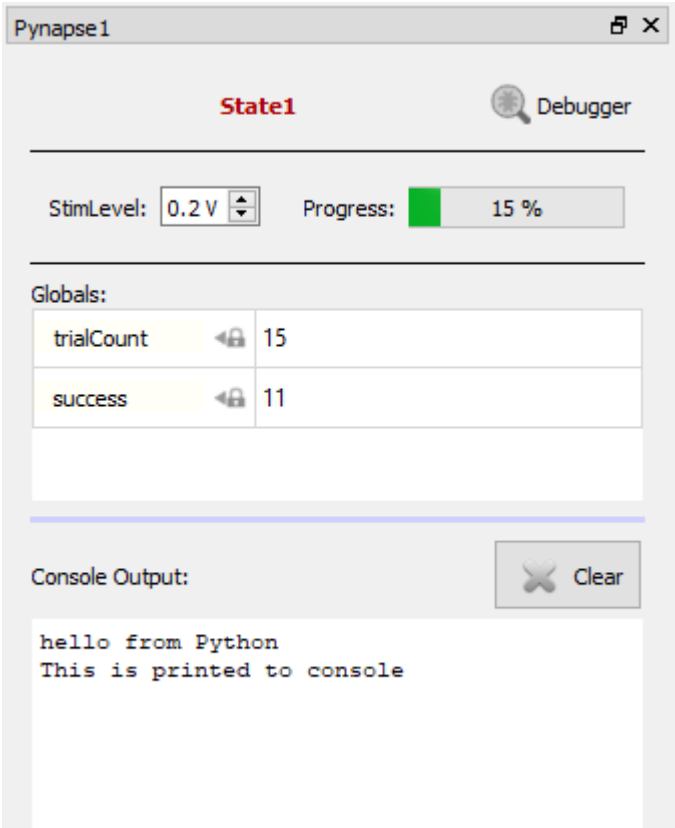
In the example below, `setTimeout` was incorrectly capitalized (should have used code completion!).



See Run-Time and Debugging for more debugging tips.

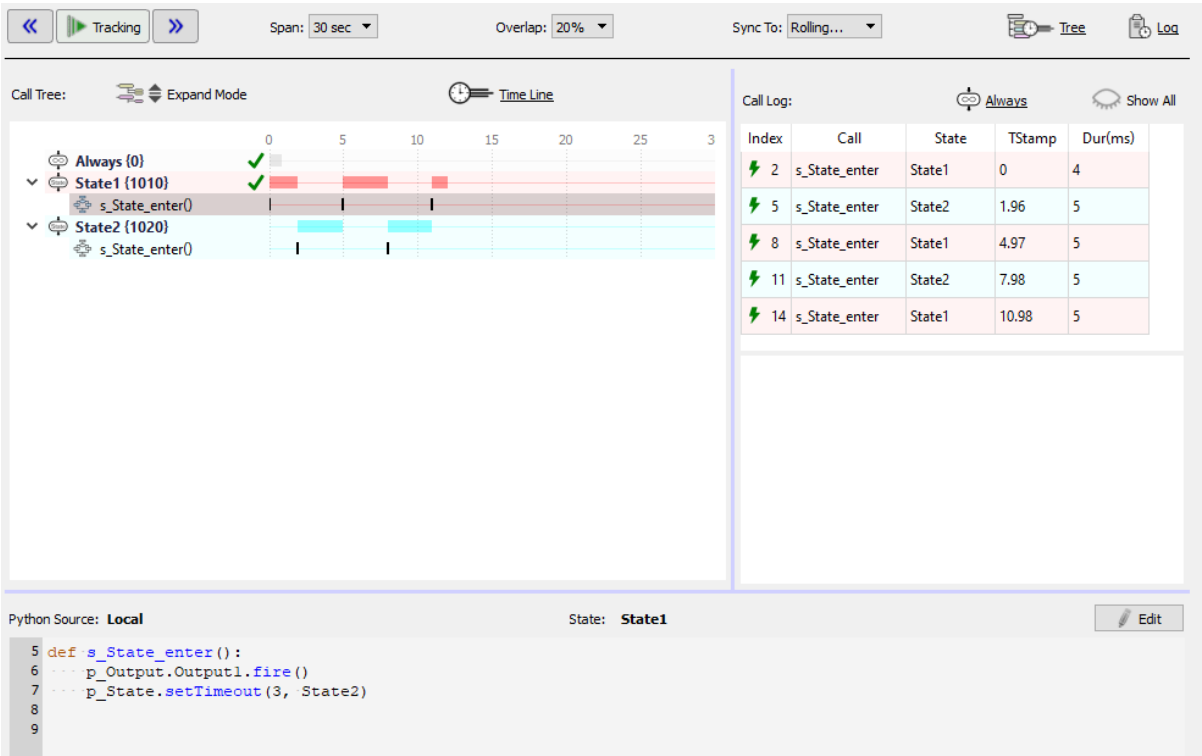
Run-Time and Debugging

The Pynapse run-time interface has two modes. The default view shows the current State in red text, any Controls and Globals assets defined at design-time, and the Console Output shows any `print` outputs or error messages from the Python code.



Debug View

Click the **Debugger** icon to open the expanded run-time view. This gives you a more in-depth look at the events in Pynapse and allows you to manipulate the Pynapse state and manually trigger events during the experiment.



Call Tree

The Call Tree shows all the states and slot methods that Pynapse knows about. An icon next to the state/slot name gives you more status information:

Icon	Description
✓	Currently active state*
⚡	A green lightning bolt is briefly shown next to successful calls.
⚠	A red warning sign is briefly shown next to calls that had errors.

> **Note**
>
> * The Always state is always also active and slot methods within it can always be triggered by Pynapse events

Expand Mode determines what methods to show within the states.

Icon	Description
	Show only the states and no slot methods
	Show all slot methods within current state
	Show all slot methods within all states

Time Line

The Time Line shows when a state is active and when slot methods fired. If there was an error during the slot method, it will show a red bar. You can click on events in the time line to see more information about it in the Call Log.

The controls at the top can stop/resume the time line, or move backward/ forward in time for review.

Span is how much time to show in the time line. When it gets to the end it clears the time line and starts drawing from the left. **Overlap** is what percentage of the end of the previous time line to include when the time line refreshes.

Sync To can be used to reset the time line when a particular state change happens, so you can easily follow the events in a particular state. This is helpful for debugging rapid events using a short time **Span**.

Call Log

All Pynapse events are captured in the Call Log with a timestamp and the amount of time spent in that method.

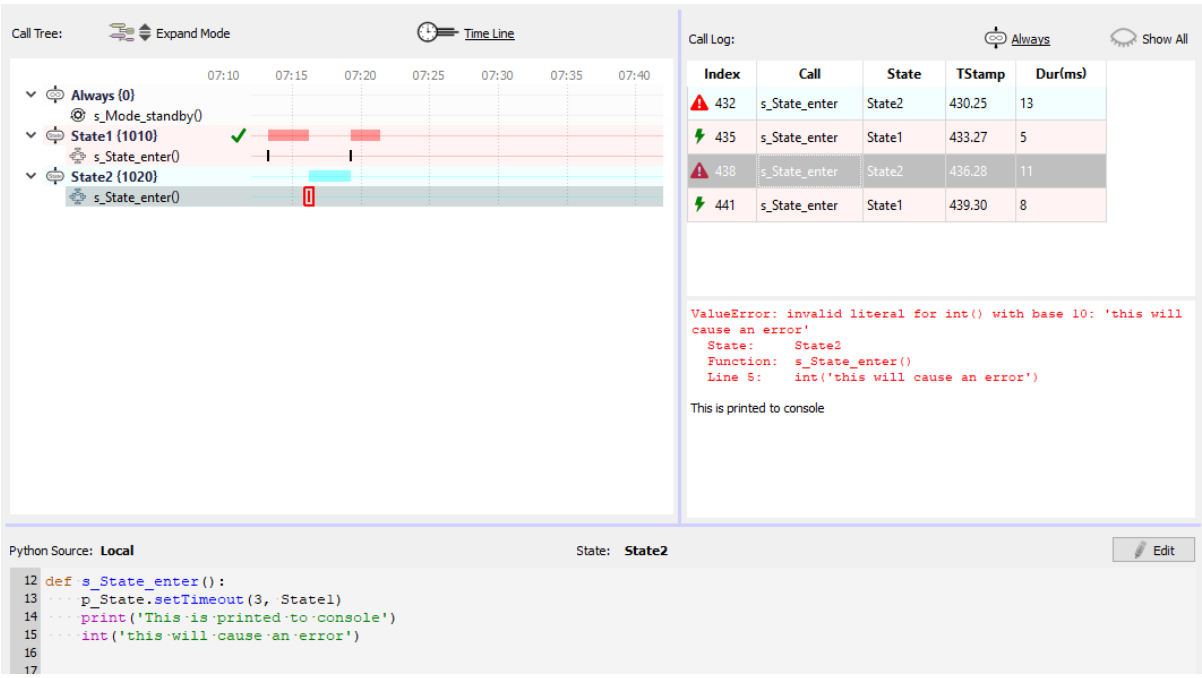
> **Tip**
>
> The information shown here is also optionally saved to a text file with the rest of your data. Enable the **Call Logging** setting in the General Tab at design-time.

Icon	Description
	You can optionally exclude the 'Always' state calls by turning off the **Always** button.
	The Show All button will show every Pynapse event, including state timeouts, internal state changes, and global variable changes.
	A green lightning bolt is shown next to successful calls.
	A red warning sign is shown next to calls that had errors.

If you click on an event in the call log, that event will be highlighted in the Call Tree, and vice versa. If it was an error, it will be outlined in red.

The window underneath the call log shows the console output for the selected call, including any error messages generated by that call, so you can track it down in the source code.

> **Note**
>
> Pause the time line so the Call Log doesn't refresh while you are trying to look at the error messages



Debugging

Manual Control

You can manually control the state flow in the Call Tree. Double-click on any state to switch Pynapse into that state. The event will be capture in the Call Log.

You can also double-click on a slot method to trigger it manually. This will not be captured in the call log.

> **Important**
>
> The **Allow Run-Time Call Control** check box on the General Tab at design-time must be enabled for manual control to work.

Live Code Editing

The bottom of the Debugging window is a view of the source code. Click on a state or a slot method in the Call Tree to see its source. Click the **Edit** button to make live changes to the code. Changes made here will be immediately applied the next time the slot fires.

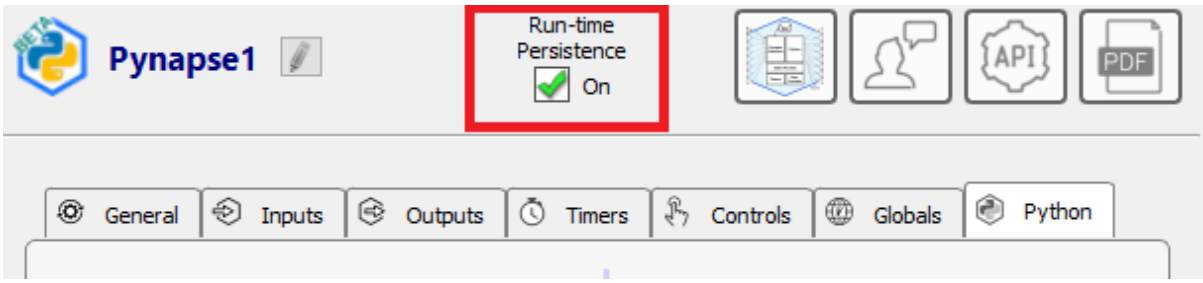
> **Caution**
>
> Live Edits will reload the State class and reinitialize any state variables. In the example below, the `ct` variable that is a member of MyState will reset to 0 if changes are made to any slot method within MyState during runtime debugging.

```
class MyState:   #StateID = ?
    ct = 0
    def s_MyInput_rise():
        print(State2.ct)
        p_Output.MyOutput.fire()
        State2.ct += 1
```

> **Important**
>
> The **Allow Run-Time Edits** check box on the General Tab at design-time must be enabled for manual control to work.

Important

If Run-time Persistence for this gizmo is enabled, those changes will apply to your experiment source code when you go back to run-time, otherwise those changes are lost.



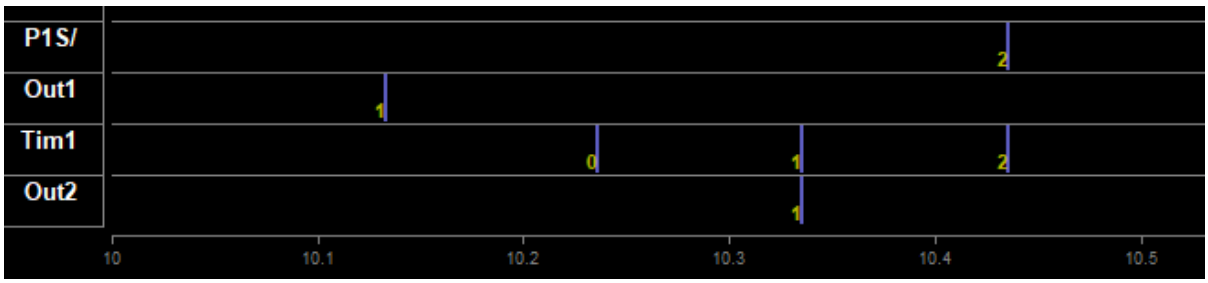
Tips and Tricks

Synchronizing Events

By default, all outputs in the Python code are executed sequentially as they are written, In the example below, outputs and timers are turned on in a slot method. The `sleep` statements are used to exaggerate the effect by adding additional latency between each call.

```
class MyState1: #StateID = 1
    def s_MyInput_rise():

        p_Output.MyOutput1.fire()
        time.sleep(0.1)

        p_Timer.MyTimer1.setPeriod(.1)
        p_Timer.MyTimer1.setRepeats(3)
        p_Timer.MyTimer1.start()
        time.sleep(0.1)

        p_Output.MyOutput2.fire()
        time.sleep(0.1)

        p_State.switch(MyState2)
```

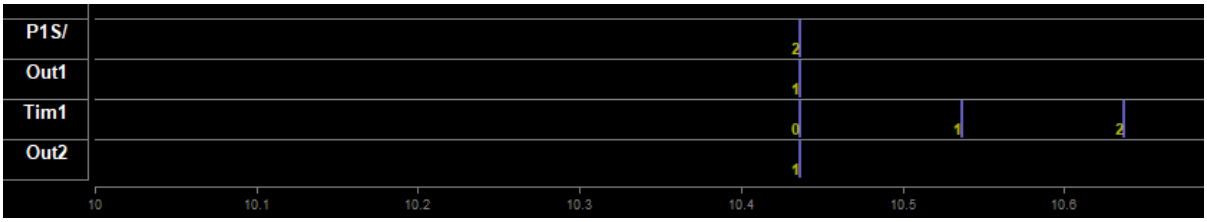
The two outputs and the timer have 'Epoc Save' turned on. The runtime output looks like this:



Event	Description
P1S/	State change event timestamp
Out1	Output1 fired
Tim1	Timer1 ticked
Out2	Output2 fired

You can see the noticeable 100 ms gaps in between the output events, and all of these events occur before the state change ('P1S/' = 2 in this example).

For coordinating stimulus events or anything else that has to happen on the hardware simultaneously, the Outputs, Parameters, and Timers have a **Sync to State Change** option. If all of the outputs and timers in the last example had this option enabled, then the result looks like this:



The `sleep` delays are still there but now all outputs fire precisely when the state changed to 2.

> **Important**
>
> The `p_State.switch` statement must come *after* any calls to set the timers or outputs for this to work properly.

Delays

The polling loop delay depends on the 'Polling Rate' setting in the Pynapse General Tab. The typical round-trip delays (read Pynapse input → set Pynapse output) are shown below.

Polling Rate Maximum	Delay
enabled	4-5 ms
disabled	~40 ms

For tighter behavioral state control, always enable Maximum Polling Rate.

> **Note**
>
> Maximum polling rate is not available when using Corpus hardware emulation

> **Note**
>
> If using the SynapseAPI class in Pynapse, there is a variable delay that ranges from 5 to 30 ms. If the computer is under heavy processing, there can be delay spikes up to ~100 ms.

Important

Global and Control asset 'writes' go through the SynapseAPI and have a longer delay.

Any calls that 'read' an asset value (except for Globals which are python variables) also go through the SynapseAPI.

Runtime Plots

If you would like to do online plotting or make your own custom GUIs then matplotlib and ipykernel==4.10.1 must also be installed in your Python environment.

If you want to plot something on screen using matplotlib you must include this line of code at the top of your Python code:

```
%matplotlib
```

Note about using a different matplotlib backend

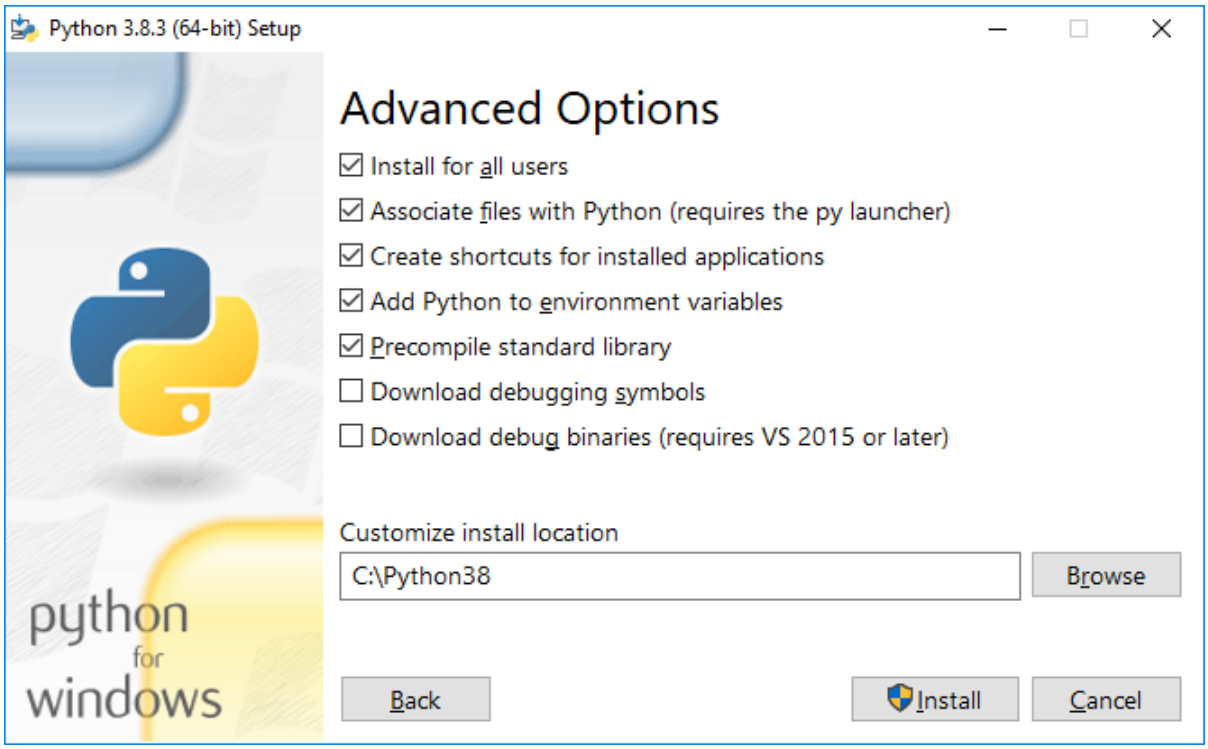
If for some reason you need to set the matplotlib backend is set, once it is set it cannot be changed for the entire interpreter session. For example, if in between recordings you change `%matplotlib qt` to `%matplotlib tk`, the second statement is ignored and qt backend will be used. If Pynapse code gets modified such that a different backend is used, a complete restart of Synapse is required.

Installing Standard Python

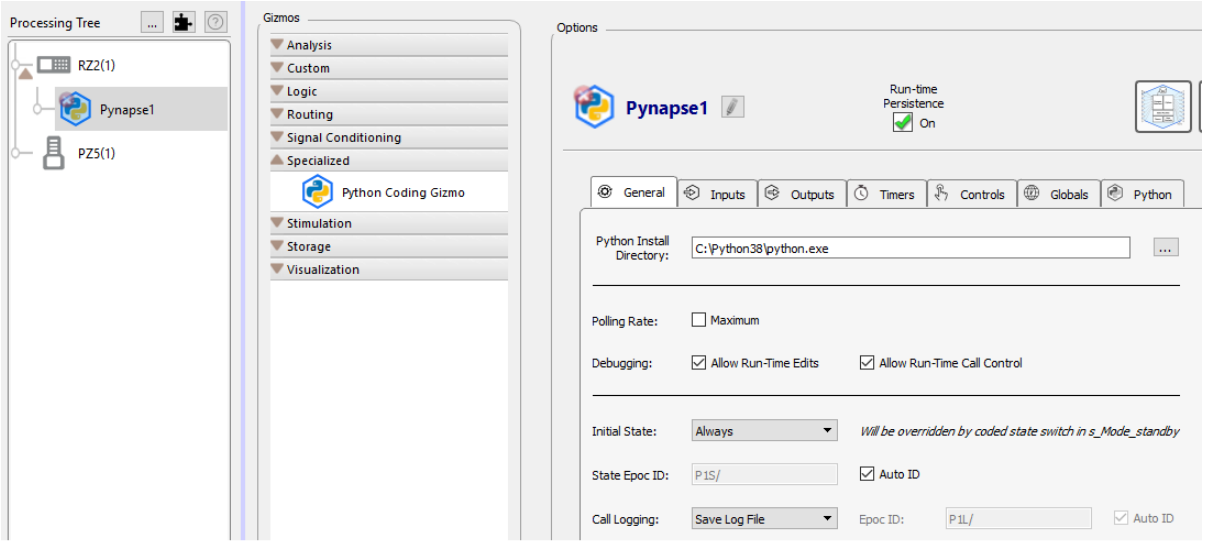
Standard python.exe installs from https://www.python.org/downloads/windows/

> **Note**
>
> We recommend installing 64-bit Python on 64-bit Windows 10. This is the Python 3.x.x "Windows x86-64 executable installer" option.
>
> On 32-bit machines, install the Python 3.x.x "Windows x86 executable installer".

1. During installation, select 'Customize Installation'
    a. Select 'Install for All Users' and 'Add Python to environment variables'
    b. Change the installation directory to C:\Python3\



2. In Synapse, add a Python Coding Gizmo from the Specialized gizmo list.



3. In Pynapse General Tab, set the Python Install Directory to your installed Python, which in this case is:

   `C:\Python3\python.exe`

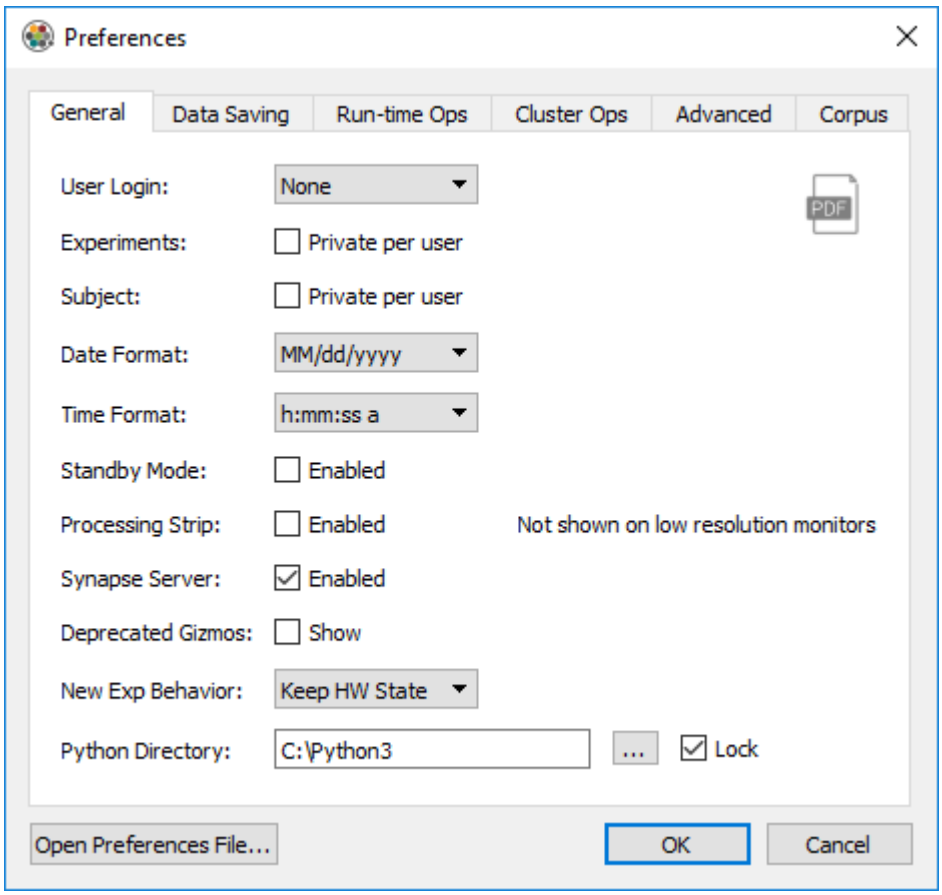
4. You will likely get an error that says it is missing ipykernel. There is one more step. Go to Windows command prompt (Start → "cmd"), and type:

   `pip install ipykernel==4.10.0`

> **Note**
>
> This specific version of ipykernel is for matplotlib support. If you want to use Pynapse for online plotting, install matplotlib:
>
> `pip install matplotlib`
>
> Install the tdt package for data analysis:
>
> `pip install tdt`

5. Back in Synapse, press F7 to recompile the experiment, which also tries to load Pynapse again. If everything is successful you should get no error message.

6. In Synapse, go to Menu → Preferences. The Python Directory will have updated to the path you just used. Select 'Lock' so this path is the default path whenever you use a Pynapse gizmo.



Environments

Pynapse also works in Python virtual environments. A virtual environment is a self-contained directory tree that contains a Python installation for a particular version of Python, plus a number of additional packages.

Environments are simply directories on disk, so it is easy to delete/recreate environments if they get in a bad state. It is more difficult to do this with the 'base' environment that installs with your Python installer. It is recommended that you create a specific environment for Pynapse to use.

Environments are created in standard python.exe installation with the venv module.

From the command line:

```
python -m venv C:\Python38\envs\pynapse
```

Then in Pynapse in the General Tab, your Python Install Directory would be:

```
C:\Python38\envs\pynapse\Scripts\python.exe
```

To install pip packages from the command line (Start → cmd), you first activate the environment:

```
C:\Python38\envs\pynapse\Scripts\activate.bat
pip install ipykernel matplotlib pyqt5
```

Note for tkinter users

Tkinter doesn't have up-to-date Windows support. If you wish to use tkinter for a custom GUI or the tkinter backend for matplotlib then ipykernel <= 4.10.1 is a requirement.

```
pip install ipykernel==4.10.0
```

See https://github.com/ipython/ipykernel/issues/358 and https://github.com/ipython/ipykernel/issues/518.