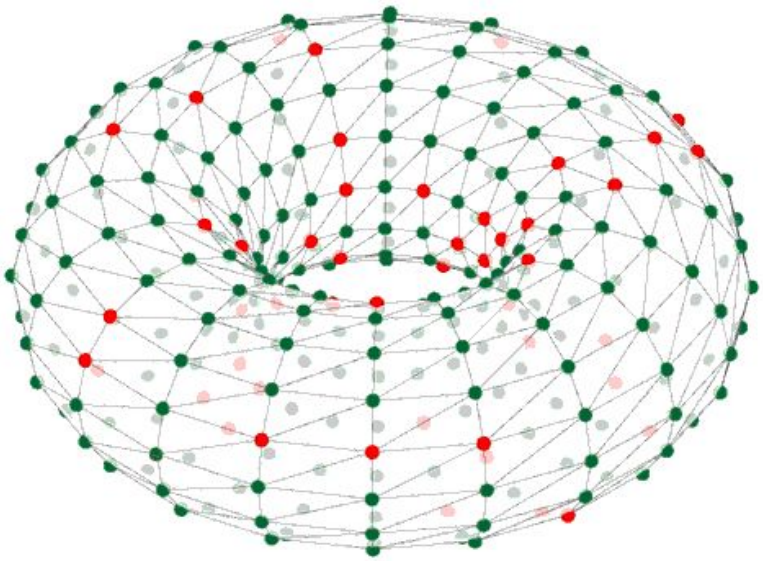
MANCHESTER 1824

Adding New Neuron Models



Andrew Gait, Andrew Rowley, Michael Hopkins

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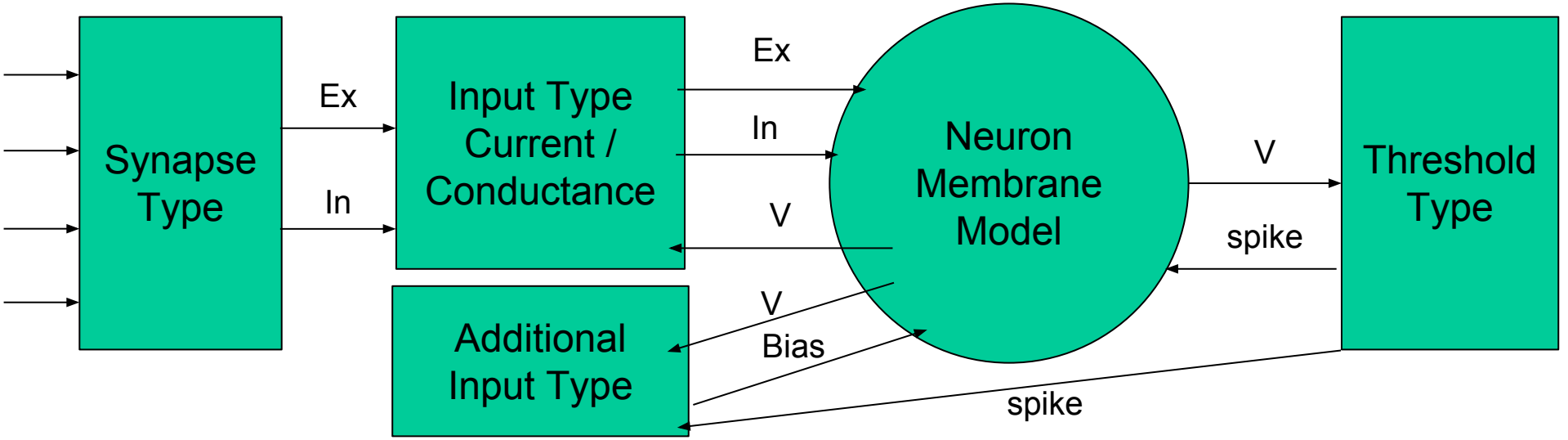
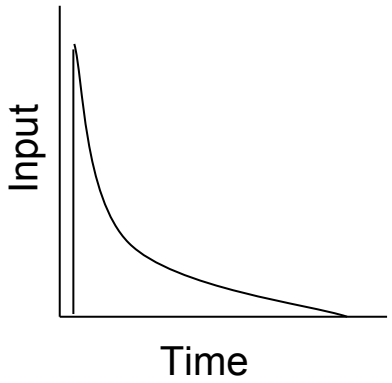
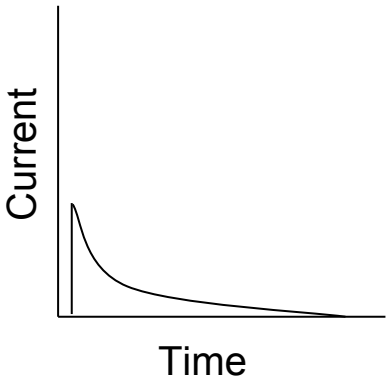
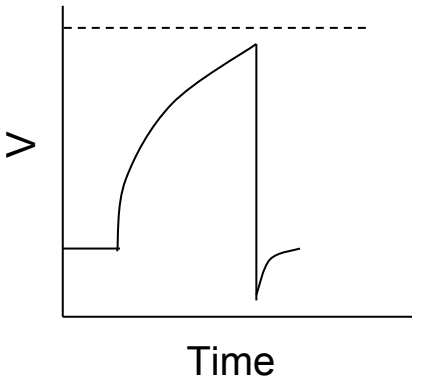
SpiNNaker

sPyNNaker Neuron Models





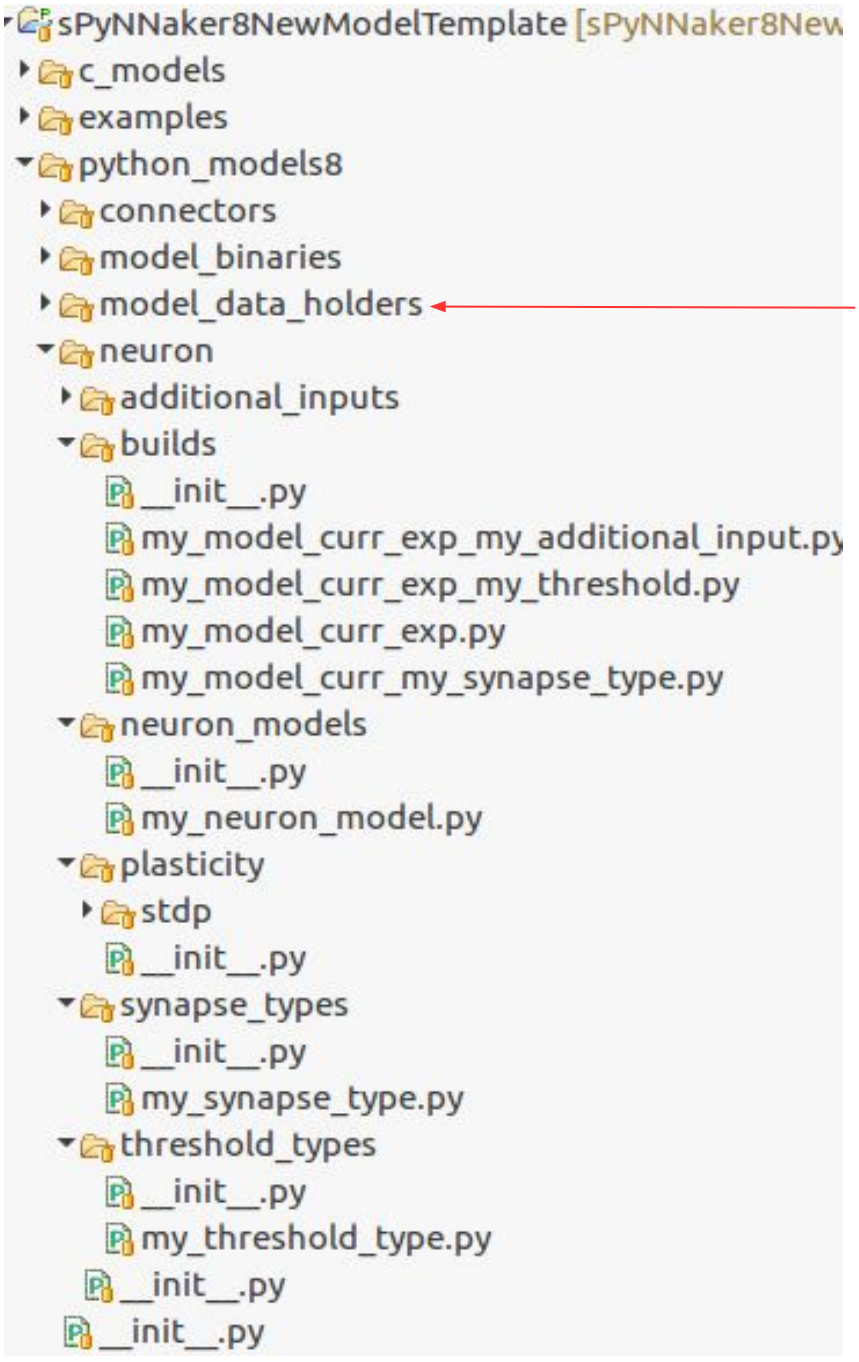




New Model Template

C code template

Python code template

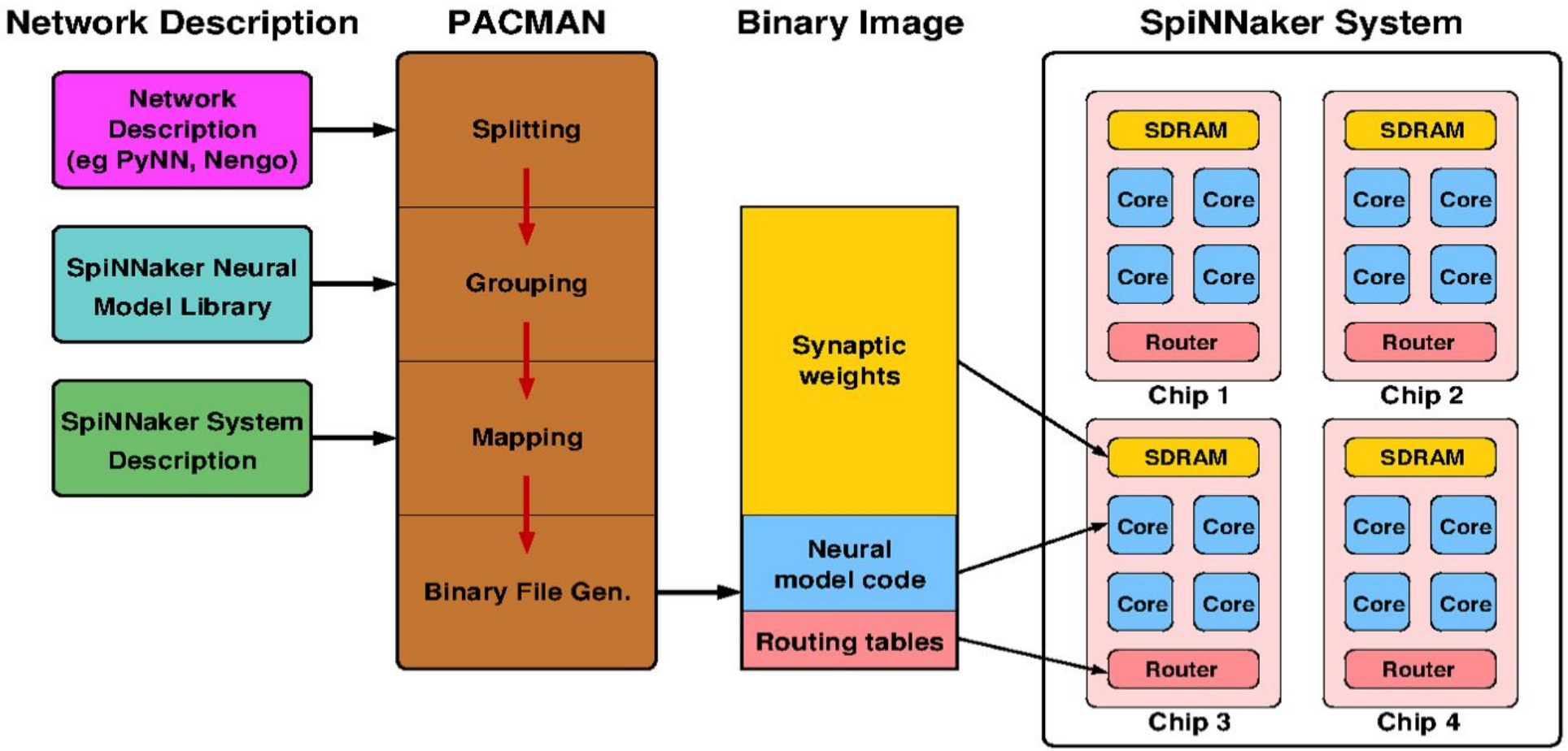


PyNN 0.8

Required code separation

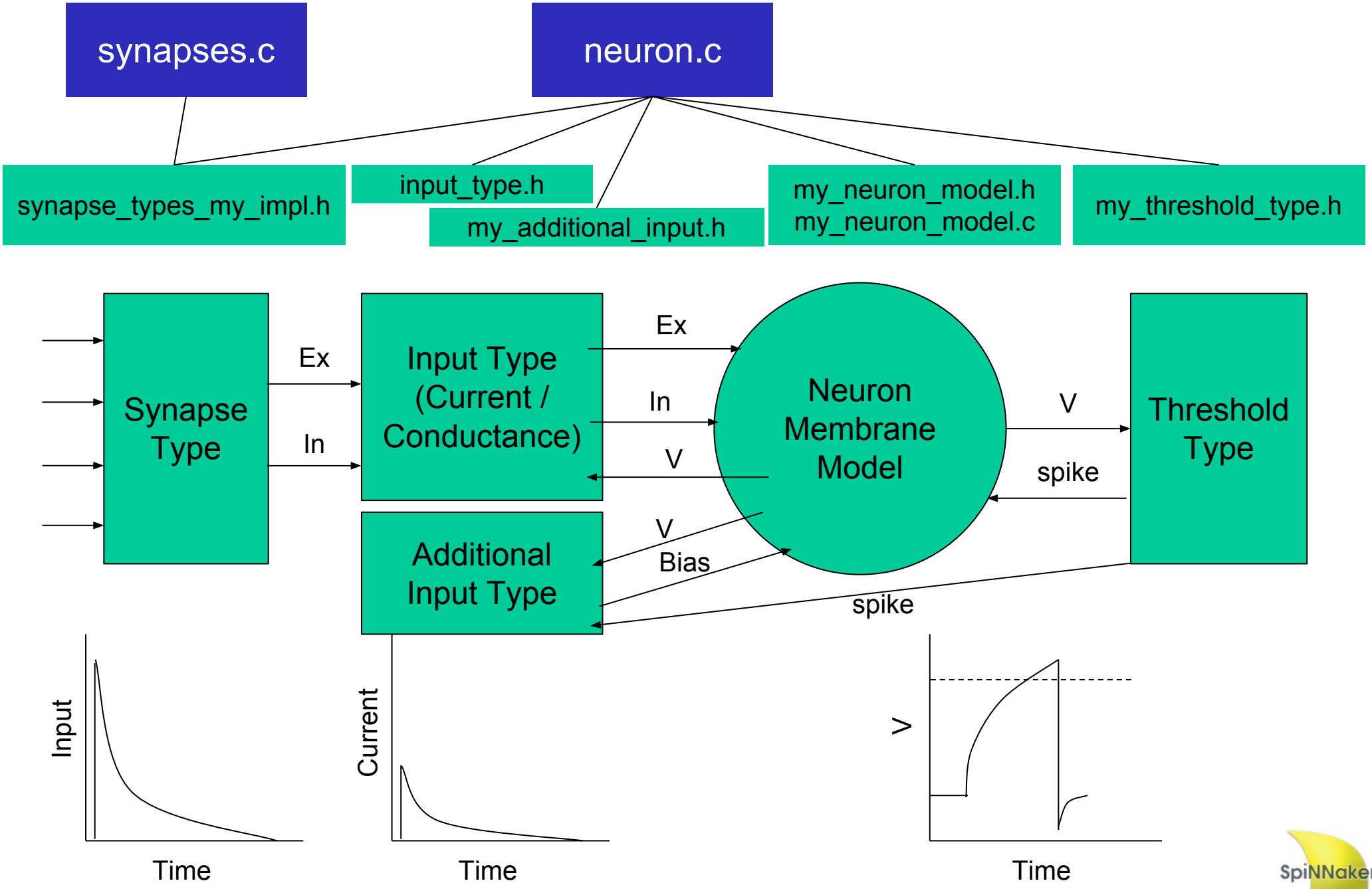
- Any new neuron model requires both C and Python code
- C code makes the actual executable (on SpiNNaker), Python code configures the setup and load phases (on the host)
- These are separate but must be perfectly coordinated
- In almost all cases, the C code will be solving an ODE which describes how the neuron state evolves over time and in response to input (as described in previous talk ***Maths & fixed-point libraries***)

Required code separation



- We will first describe the C requirements

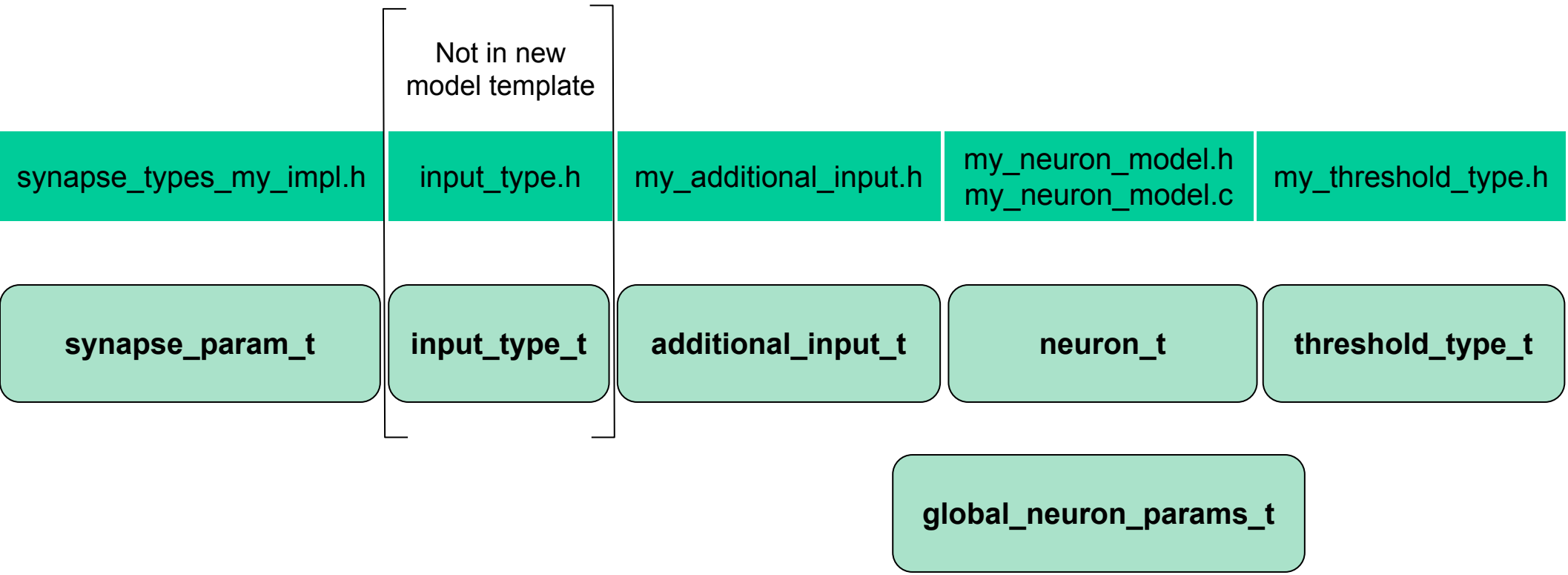
sPyNNaker Neuron Models - C



C Data Structures and Parameters

- The parameters and state of a neuron at any point in time need to be stored in memory
- For each neuron, the C header defines the ordering and size of each stored value
- The C types can be standard integer and floating-point, or ISO draft standard fixed-point, as required (see earlier talk ***Maths & fixed-point libraries***)
- There is also one global data structure which services all neurons on a core

sPyNNaker Neuron Models - C Structures



Specific neuron model - data structure

- An example of the C data structure using the Izhikevich neuron

```
#include "neuron-model.h"

//     Izhikevich neuron data struct defined in neuron_model_izh_impl.h

typedef struct neuron_t {

// nominally 'fixed' parameters - abstract units
   REAL   A;
   REAL   B;
   REAL   C;
   REAL   D;

// Variable-state parameters
   REAL   V;           // nominally in [mV]
   REAL   U;

// offset current [nA]
   REAL   I_offset;

// current timestep - simple correction for threshold
   REAL   this_h;

} neuron_t;
...
```

Neuron model: global data structure

```
...

/*
   Global data structure defined in neuron_model_izh_impl.h
*/

typedef struct global_neuron_params_t {

// Machine time step in milliseconds
   REAL   machine_timestep_ms;

} global_neuron_params_t;
```

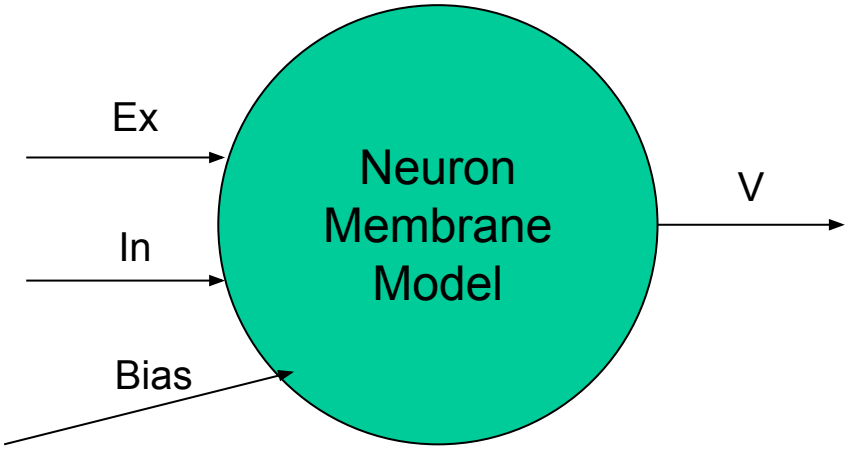
Implementing the state update (1)

- Neuron models are typically described as systems of initial value ODEs
- At each time step, the internal state of each neuron needs to be updated in response to inherent dynamics and synaptic input
- There are many ways to achieve this; there will usually be a 'best approach' (in terms of balance between accuracy & efficiency) for each neuron model

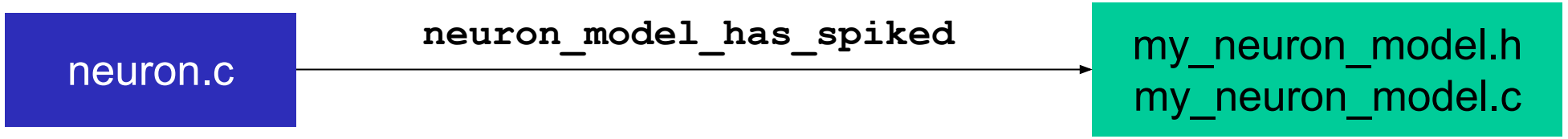
Implementing the state update (2)

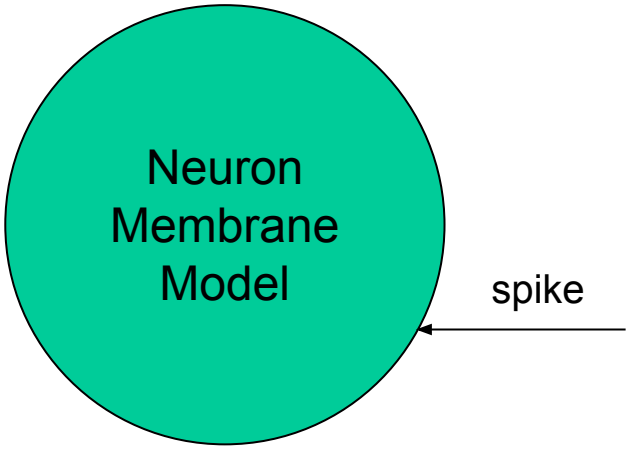
- A published paper gives a lot more detail: Hopkins & Furber (2015), “Accuracy and Efficiency in Fixed-Point Neural ODE Solvers” , *Neural Computation* **27**, 1–35
- The key function will always be *neuron_model_state_update*(); the other functions are mainly used to support this and allow debugging etc.
- Continuing the Izhikevich example by describing the key interfaces

sPyNNaker Neuron Models - C Interfaces

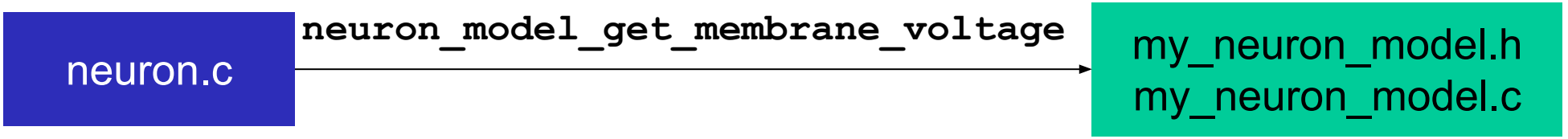


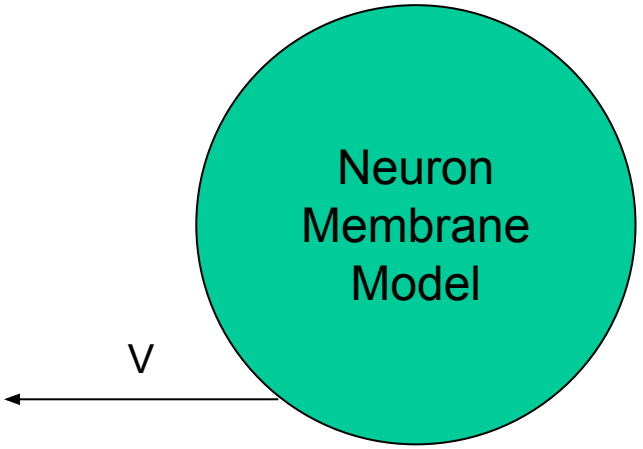
sPyNNaker Neuron Models - C Interfaces





sPyNNaker Neuron Models - C Interfaces





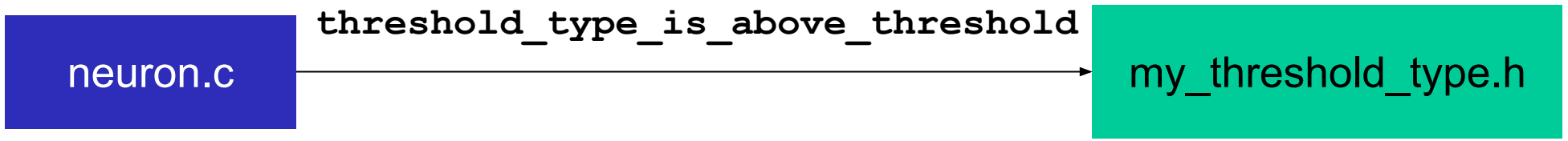
Neuron model API in neuron_model.h

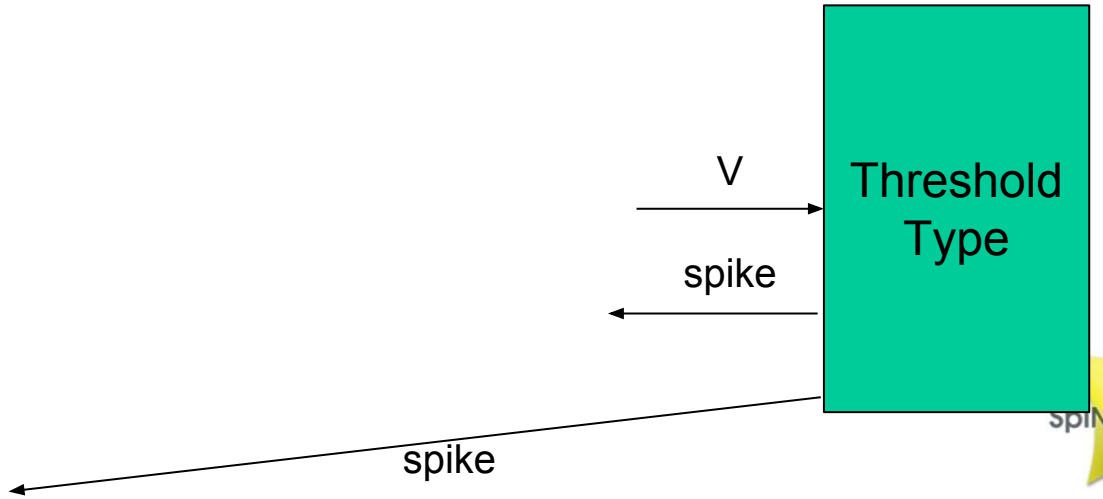
```
•
•// Forward declaration of neuron type (creates a definition for a pointer to a
•//  neuron parameter struct
•typedef struct neuron_t* neuron_pointer_t;
•
•// Forward declaration of global neuron parameters
•typedef struct global_neuron_params_t* global_neuron_params_pointer_t;
•
•// set the global neuron parameters
•void neuron_model_set_global_neuron_params(
•    global_neuron_params_pointer_t params);
•
•// primary function called in timer loop after synaptic update
•state_t neuron_model_state_update(
•                input_t exc_input, input_t inh_input, input_t external_bias,
•                neuron_pointer_t neuron );
•
•// Indicates that the neuron has spiked
•void neuron_model_has_spiked( neuron_pointer_t neuron );
•
•// Get the neuron membrane voltage for a given neuron parameter set
•state_t neuron_model_get_membrane_voltage(  restrict neuron_pointer_t neuron );
•
•// print out neuron parameters (i.e. values which don't change, for debug)
•void neuron_model_print_parameters(  restrict neuron_pointer_t neuron );
•
•// print out state variables (i.e. values that might change, for debug)
•void neuron_model_print_state_variables(  restrict neuron_pointer_t neuron );
•
```

Specific neuron model - key functions

```
// simplified version of Izhikevich neuron code defined in neuron_model_izh_impl.c

static const REAL SIMPLE_TQ_OFFSET = REAL_CONST(1.85);

// key function in timer loop that updates neuron state and returns membrane voltage
state_t neuron_model_state_update(
                input_t exc_input, input_t inh_input, input_t external_bias,
                neuron_pointer_t neuron) {

// collect inputs
    input_t input_this_timestep = exc_input - inh_input
                                    + external_bias + neuron->I_offset;

// most balanced ESR update found so far
    _rk2_kernel_midpoint(neuron->this_h, neuron, input_this_timestep);
    neuron->this_h = global_params->machine_timestep_ms;

// return the value of the membrane voltage
    return neuron->V;
}

// make the discrete changes to state after a spike has occurred
void neuron_model_has_spiked( neuron_pointer_t neuron ) {
    // reset membrane voltage
    neuron->V  = neuron->C;
    // offset 2nd state variable
    neuron->U += neuron->D;
    // simple threshold correction - next timestep (only) gets a bump
        neuron->this_h = global_params->machine_timestep_ms * SIMPLE_TQ_OFFSET;
}
```

sPyNNaker Neuron Models - C Interfaces





Threshold Models: Interface and Implementation

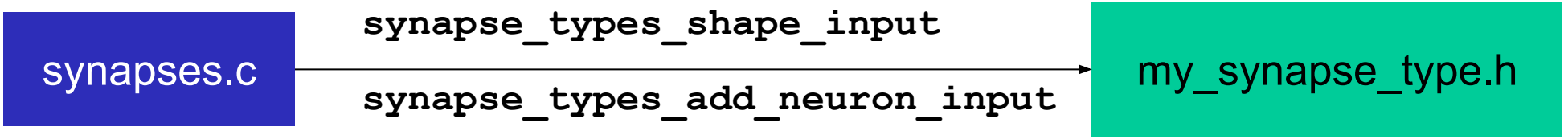
- Interface

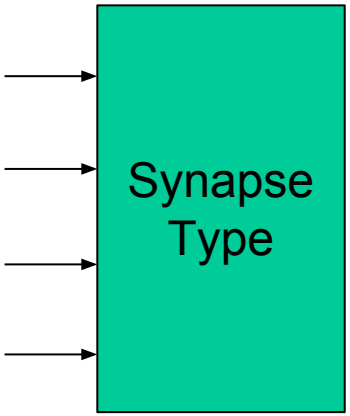
```
// Forward declaration of the threshold pointer type (used to access all operations)
typedef struct threshold_type_t* threshold_type_pointer_t;


// Determines if the value given is above the threshold value (main function)
static inline bool threshold_type_is_above_threshold(
        state_t value, threshold_type_pointer_t threshold_type );
```

- Static Threshold Implementation

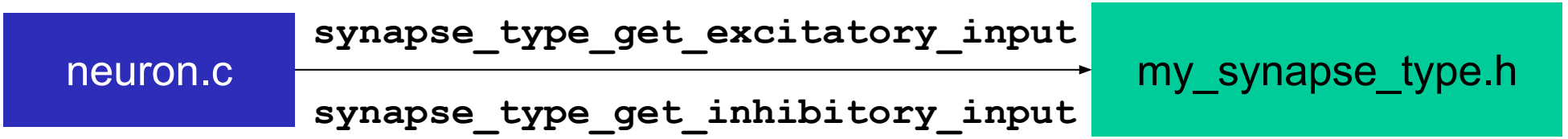
```
typedef struct threshold_type_t {

    // The value of the static threshold
    REAL threshold_value;

} threshold_type_t;


static inline bool threshold_type_is_above_threshold(state_t value,
                        threshold_type_pointer_t threshold_type) {

    return REAL_COMPARE(value, >=, threshold_type→threshold_value);
}
```

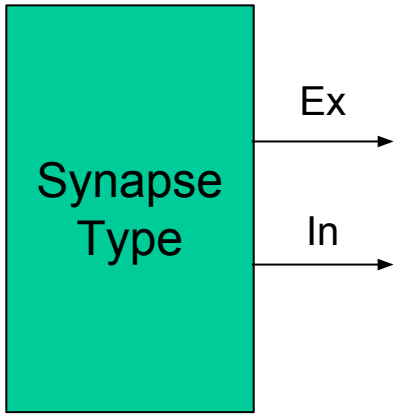
sPyNNaker Neuron Models - C Interfaces



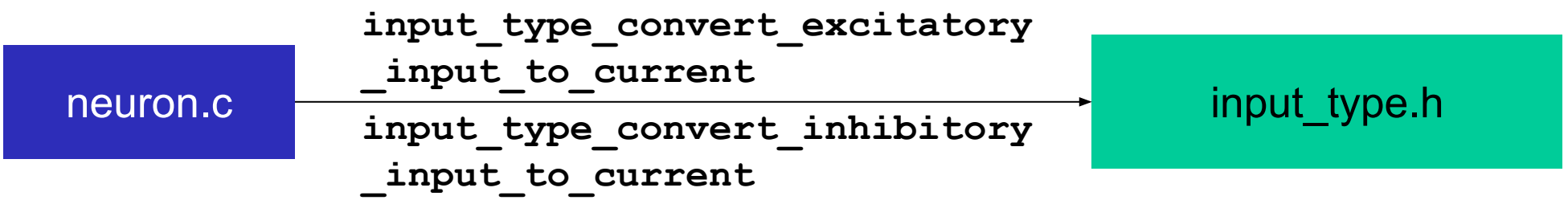


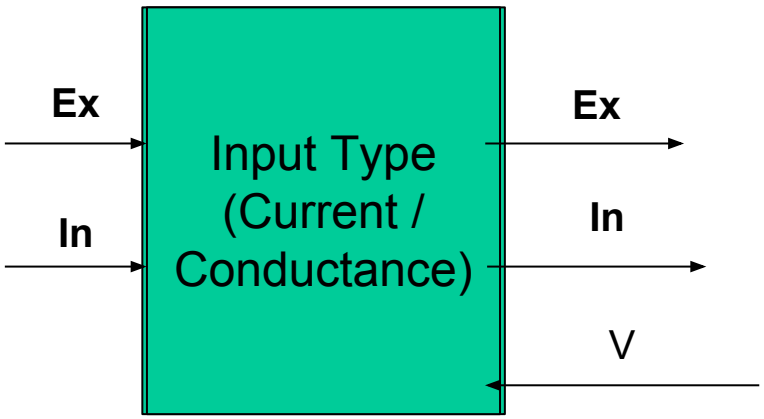
sPyNNaker Neuron Models - C Interfaces



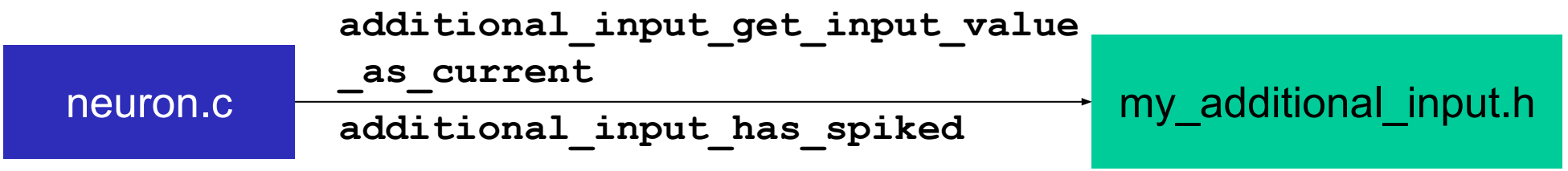


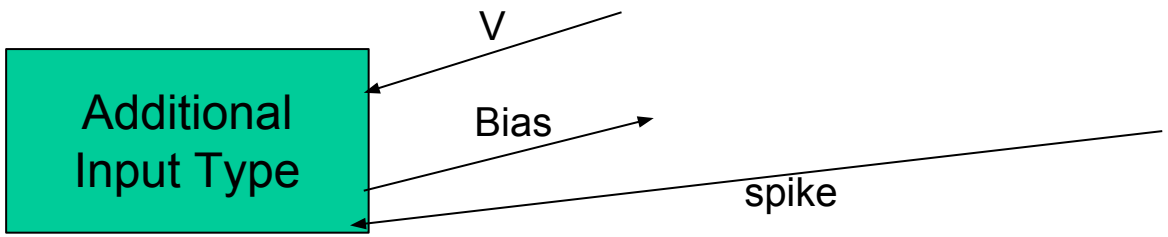
sPyNNaker Neuron Models - C Interfaces





sPyNNaker Neuron Models - C Interfaces





sPyNNaker Neuron Models - C Models

synapse_types_exponential.h

synapse_types_dual_excitatory_exponential.h

synapse_types_delta_impl.h

input_type_current.h

input_type_conductance.h

additional_input_none_impl.h

additional_input_ca2_adaptive_impl.h

neuron_model_izh_impl.c / .h

neuron_model_lif_impl.c / .h

threshold_type_static.h

threshold_type_external_device_control.h

threshold_type_maass_stochastic.h

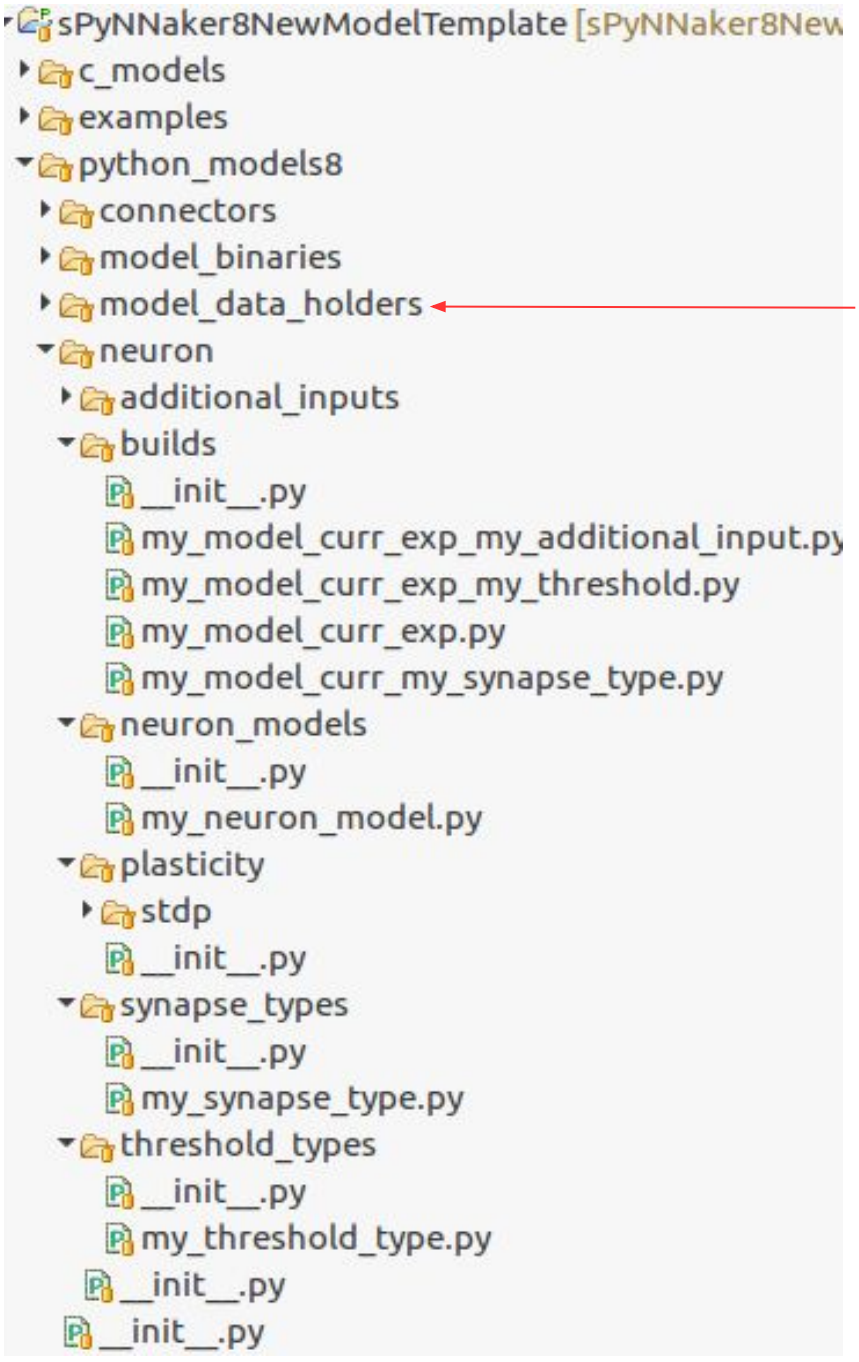
sPyNNaker Neuron Models - Makefile

```
APP = my_model_curr_exp

# This is the folder where things will be built (this will be created)
BUILD_DIR = build/

# This is the neuron model implementation
NEURON_MODEL = $(EXTRA_SRC_DIR)/neuron/models/my_neuron_model.c

# This is the header of the neuron model, containing the definition of neuron_t
NEURON_MODEL_H = $(EXTRA_SRC_DIR)/neuron/models/my_neuron_model.h

# This is the (optional) header containing the additional input type
ADDITIONAL_INPUT_H = $(EXTRA_SRC_DIR)/neuron/additional_inputs/my_additional_input.h

# This is the header containing the input type (current in this case)
INPUT_TYPE_H = $(SOURCE_DIR)/neuron/input_types/input_type_current.h

# This is the header containing the threshold type (static in this case)
THRESHOLD_TYPE_TYPE_H = $(SOURCE_DIR)/neuron/threshold_types/threshold_type_static.h

# This is the header containing the synapse shaping type (exponential in this case)
SYNAPSE_TYPE_H = $(SOURCE_DIR)/neuron/synapse_types/synapse_types_exponential_impl.h

# This is the synapse dynamics type (in this case static i.e. no synapse dynamics)
SYNAPSE_DYNAMICS = $(SOURCE_DIR)/neuron/plasticity/synapse_dynamics_static_impl.c

# This includes the common Makefile that hides away the details of the build
include ../Makefile.common
```

New Model Template

C code template

Python code template



PyNN 0.8

Python interface - Why?

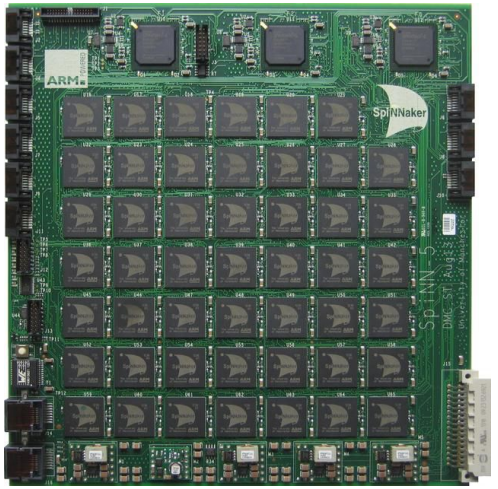
PyNN Script

sPyNNaker

PACMAN

DataSpecification

SpiNNMan



Python Interface - Parameters

- Parameters can be:
  - Individual values
  - Array of values (one per neuron)
  - RandomDistribution

- Normalise Parameters (in the __init__ function)
  - utility_calls.convert_param_to_numpy(
    param, n_neurons)

sPyNNaker Neuron Models - Python

AbstractPopulationVertex → MyNeuronModel

```
get_n_cpu_cycles_per_neuron
get_n_neural_parameters
get_n_global_parameters
get_neural_parameters
get_global_parameters
get_neural_parameter_types
```

C

```
struct my_input_type {
  accum  param_1;
  uint32 param_2;
  accum  state_var;
}
```

3

Python

```
[
 NeuronParameter(self._param_1, DataType.S1615)
 NeuronParameter(self._param_2, DataType.UINT32)
 NeuronParameter(self._var_init, DataType.S1615)
]
```

Specific neuron model - data structure

- An example of the C data structure using the Izhikevich neuron

```
#include "neuron-model.h"

//     Izhikevich neuron data struct defined in neuron_model_izh_impl.h

typedef struct neuron_t {

// nominally 'fixed' parameters - abstract units
   REAL   A;
   REAL   B;
   REAL   C;
   REAL   D;

// Variable-state parameters
   REAL   V;           // nominally in [mV]
   REAL   U;

// offset current [nA]
   REAL   I_offset;

// current timestep - simple correction for threshold
   REAL   this_h;

} neuron_t;
...
```

Python Interface: DataType

```
from spynnaker.pyNN.models.neuron.neuron_models.abstract_neuron_model \
    import AbstractNeuronModel
from spynnaker.pyNN.models.abstract_models  import AbstractContainsUnits

from data_specification.enums  import DataType

from enum import Enum


class _IZH_TYPES(Enum)
    A = (1, DataType.S1615)
    B = (2, DataType.S1615)
    C = (3, DataType.S1615)
    D = (4, DataType.S1615)
    V_INIT = (5, DataType.S1615)
    U_INIT = (6, DataType.S1615)
    I_OFFSET = (7, DataType.S1615)
    THIS_H = (8, DataType.S1615)

    def __new__(cls, value, data_type):
        obj = object.__new__(cls)
        obj._value_ = value
        obj._data_type = data_type
        return obj

    @property
    def data_type(self):
        return self._data_type
```

Python Interface: DataType

```
from spynnaker.pyNN.models.neuron.neuron_models.abstract_neuron_model \
    import AbstractNeuronModel
from spynnaker.pyNN.models.abstract_models  import AbstractContainsUnits

from data_specification.enums  import DataType

from enum import Enum
    ...


class _IZH_GLOBAL_TYPES(Enum):
    TIMESTEP = (1, DataType.S1615)

    def __new__(cls, value, data_type):
        obj = object.__new__(cls)
        obj._value_ = value
        obj._data_type = data_type
        return obj

    @property
    def data_type(self):
        return self._data_type

class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):

    def __init__(self, n_neurons, a, b, c, d, v_init, u_init, i_offset):
        AbstractNeuronModel.__init__( self)
        AbstractContainsUnits.__init__( self)
        self._n_neurons = n_neurons
```

Python Interface - initializer

```
from spynnaker.pyNN.models.neuron.neuron_models.abstract_neuron_model \
    import AbstractNeuronModel
from spynnaker.pyNN.models.abstract_models  import AbstractContainsUnits
    ...


class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    def __init__(self, n_neurons, a, b, c, d, v_init, u_init, i_offset):
        AbstractNeuronModel.__init__( self)
        AbstractContainsUnits.__init__( self)

        self._units = {
            'a' : "ms",
            'b' : "ms",
            'c' : "mV",
            'd' : "mV/ms",
            'v_init' : "mV",
            'u_init' : "mV/ms",
            'i_offset' : "nA"}

        self._n_neurons = n_neurons
        self._a = utility_calls.convert_param_to_numpy(a, n_neurons)
        self._b = utility_calls.convert_param_to_numpy(b, n_neurons)
        self._c = utility_calls.convert_param_to_numpy(c, n_neurons)
        self._d = utility_calls.convert_param_to_numpy(d, n_neurons)
        self._v_init = utility_calls.convert_param_to_numpy(v_init, n_neurons)
        self._u_init = utility_calls.convert_param_to_numpy(u_init, n_neurons)
        self._i_offset = utility_calls.convert_param_to_numpy(
            i_offset, n_neurons)
```

Python Interface - properties

```
class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    ...


    @property
    def a(self):
        return self._a

    @a.setter
    def a(self, a):
        self._a = utility_calls.convert_param_to_numpy(a,  self._n_neurons)


    @property
    def b(self):
        return self._b

    @b.setter
    def b(self, b):
        self._b = utility_calls.convert_param_to_numpy(b,  self._n_neurons)


    ...
```

Python Interface - state initializers

```
class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    ...

    def initialize_v(self, v_init):
        self._v_init = utility_calls.convert_param_to_numpy(v_init,  self._n_neurons)

    def initialize_u(self, u_init):
        self._u_init = utility_calls.convert_param_to_numpy(u_init,  self._n_neurons)
```

Python Interface - parameters

```
class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    ...
    @overrides(AbstractNeuronModel.get_n_neural_paramters)
    def get_n_neural_parameters(self):
        return 8

    @inject_items({"machine_time_step": "MachineTimeStep"})
    @overrides(AbstractNeuronModel.get_neural_paramters,
               additional_arguments={ 'machine_time_step' })
    def get_neural_parameters(self, machine_time_step):
        return [
            # REAL A
            NeuronParameter( self._a, _IZH_TYPES.A.data_type),
            # REAL B
            NeuronParameter( self._b, _IZH_TYPES.B.data_type),
            # REAL C
            NeuronParameter( self._c, _IZH_TYPES.C.data_type),
            # REAL D
            NeuronParameter( self._d, _IZH_TYPES.D.data_type),
            # REAL V
            NeuronParameter( self._v_init, _IZH_TYPES.V_INIT.data_type),
            # REAL U
            NeuronParameter( self._u_init, _IZH_TYPES.U_INIT.data_type),
            # REAL I_offset
            NeuronParameter( self._i_offset, _IZH_TYPES.I_OFFSET.data_type),
            # REAL this_h
            NeuronParameter(
               machine_time_step / 1000.0, _IZH_TYPES.THIS_H.data_type)
        ]
```

Python Interface - global parameters

```
class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    ...


    def get_n_global_parameters(self):
        return 1


    @inject_items({"machine_time_step": "MachineTimeStep"})
    @overrides(AbstractNeuronModel.get_neural_paramters,
               additional_arguments={ 'machine_time_step' })
    def get_global_parameters(self, machine_time_step):
        return [
            NeuronParameter(
                machine_time_step /  1000.0,
                _IZH_GLOBAL_TYPES.TIMESTEP.data_type)
        ]

    @overrides(AbstractNeuronModel.get_global_parameter_types)
    def get_global_parameter_types(self):
        return [item.data_type for item in _IZH_GLOBAL_TYPES]
```

Python Interface - injection

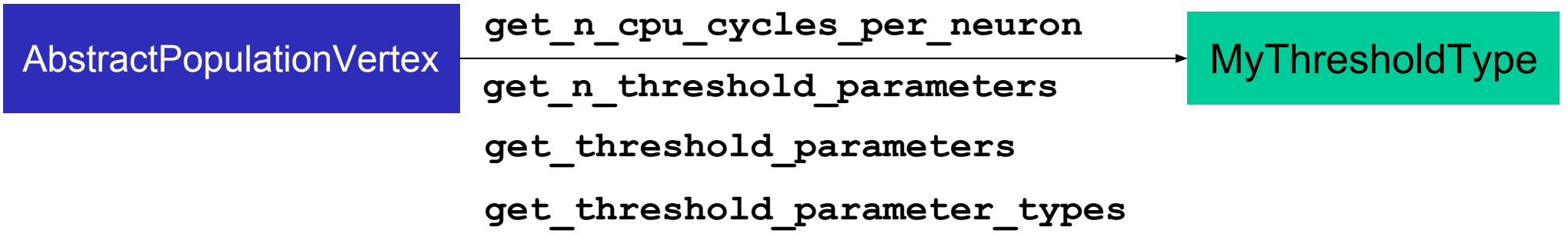
```
@inject_items({"machine_time_step": "MachineTimeStep"})
def get_global_parameters(self, machine_time_step):
```

- Some items can be “injected” from the interface
  - Specify a dictionary of parameter name to “type” to inject
  - Parameter is in addition to the interface
- Common types include:
  - MachineTimeStep
  - TimeScaleFactor
  - TotalRunTime

Python Interface - CPU usage

```
class NeuronModelIzh(AbstractNeuronModel, AbstractContainsUnits):
    ...

    def get_n_cpu_cycles_per_neuron(self):

        # A bit of a guess
        return 150
```

sPyNNaker Neuron Models - Python



Threshold Models: Interface and Implementation

- Interface

```
// Forward declaration of the threshold pointer type (used to access all operations)
typedef struct threshold_type_t* threshold_type_pointer_t;


// Determines if the value given is above the threshold value (main function)
static inline bool threshold_type_is_above_threshold(
        state_t value, threshold_type_pointer_t threshold_type );
```

- Static Threshold Implementation

```
typedef struct threshold_type_t {

    // The value of the static threshold
    REAL threshold_value;

} threshold_type_t;


static inline bool threshold_type_is_above_threshold(state_t value,
                        threshold_type_pointer_t threshold_type) {

    return REAL_COMPARE(value, >=, threshold_type→threshold_value);
}
```

Python Interface - Threshold type

```
class ThresholdTypeStatic(AbstractThresholdType, AbstractContainsUnits):
    """ A threshold that is a static value
    """


    def __init__(self, n_neurons, v_thresh):
        AbstractThresholdType.__init__( self)
        AbstractContainsUnits.__init__( self)

        self._units = {'v_thresh': "mV"}

        self._n_neurons = n_neurons
        self._v_thresh = utility_calls.convert_param_to_numpy(
            v_thresh, n_neurons)
```

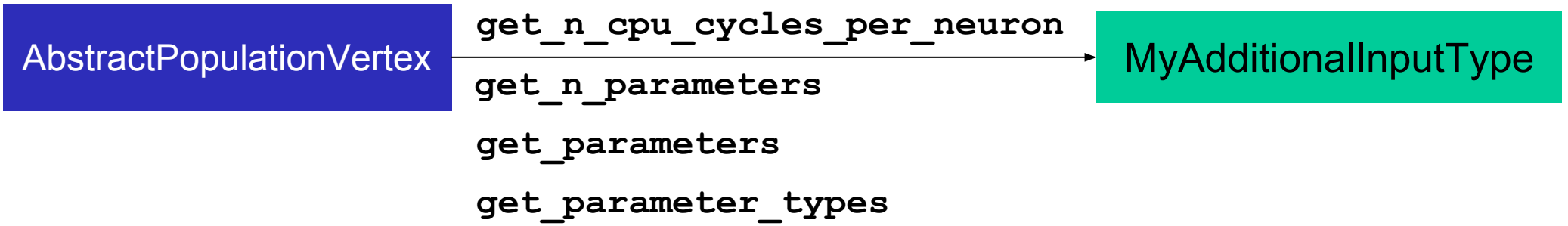
Python Interface - Threshold type

```
class ThresholdTypeStatic(AbstractThresholdType, AbstractContainsUnits):
    """ A threshold that is a static value
    """
    ...


    @property
    def v_thresh(self):
        return self._v_thresh


    @v_thresh.setter
    def v_thresh(self, v_thresh):
        self._v_thresh = utility_calls.convert_param_to_numpy(
            v_thresh, self._n_neurons)
```

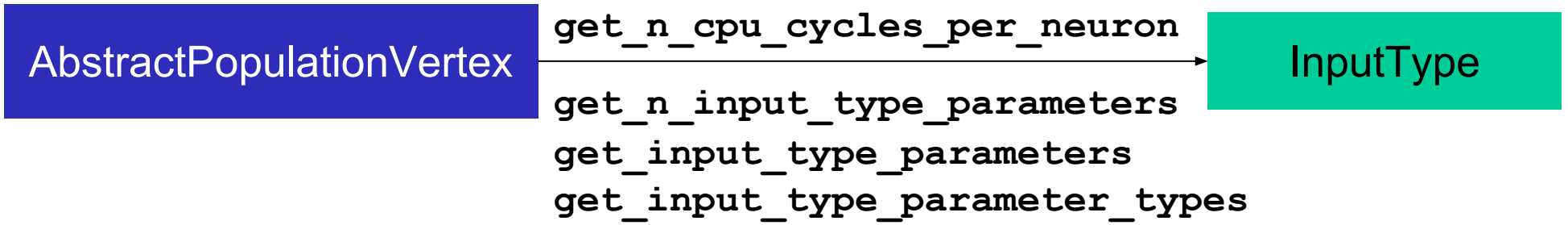
Python Interface - Threshold type

```
class ThresholdTypeStatic(AbstractThresholdType, AbstractContainsUnits):
    """ A threshold that is a static value
    """
    ...


    def get_n_threshold_parameters(self):
        return 1


    def get_threshold_parameters(self):
        return [
            NeuronParameter( self._v_thresh, _STATIC_TYPES.V_THRESH.data_type)
        ]


    def get_n_cpu_cycles_per_neuron(self):


        # Just a comparison, but 2 just in case!
        return 2
```

sPyNNaker Neuron Models - Python



sPyNNaker Neuron Models - Python

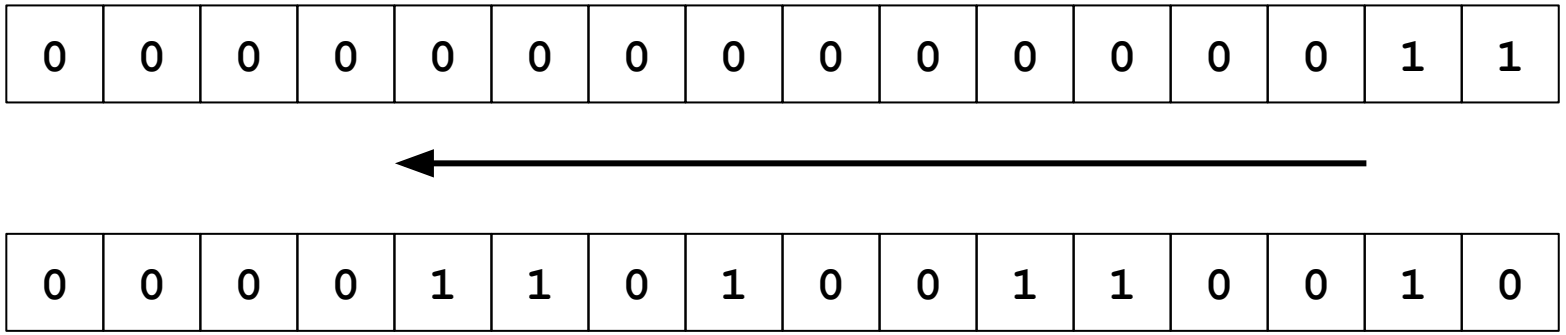


sPyNNaker Neuron Models - Python

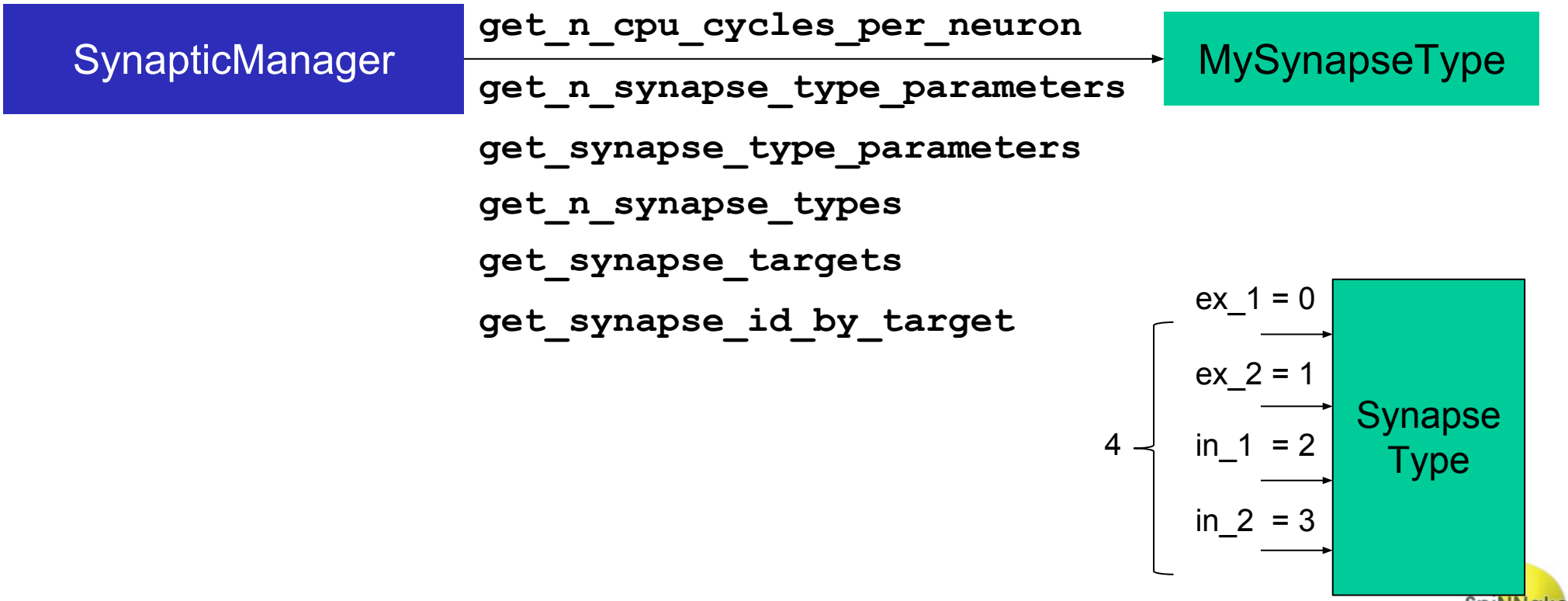
AbstractPopulationVertex

```
get_n_cpu_cycles_per_neuron
get_n_input_type_parameters
get_input_type_parameters
get_input_type_parameter_types
get_global_weight_scale
```

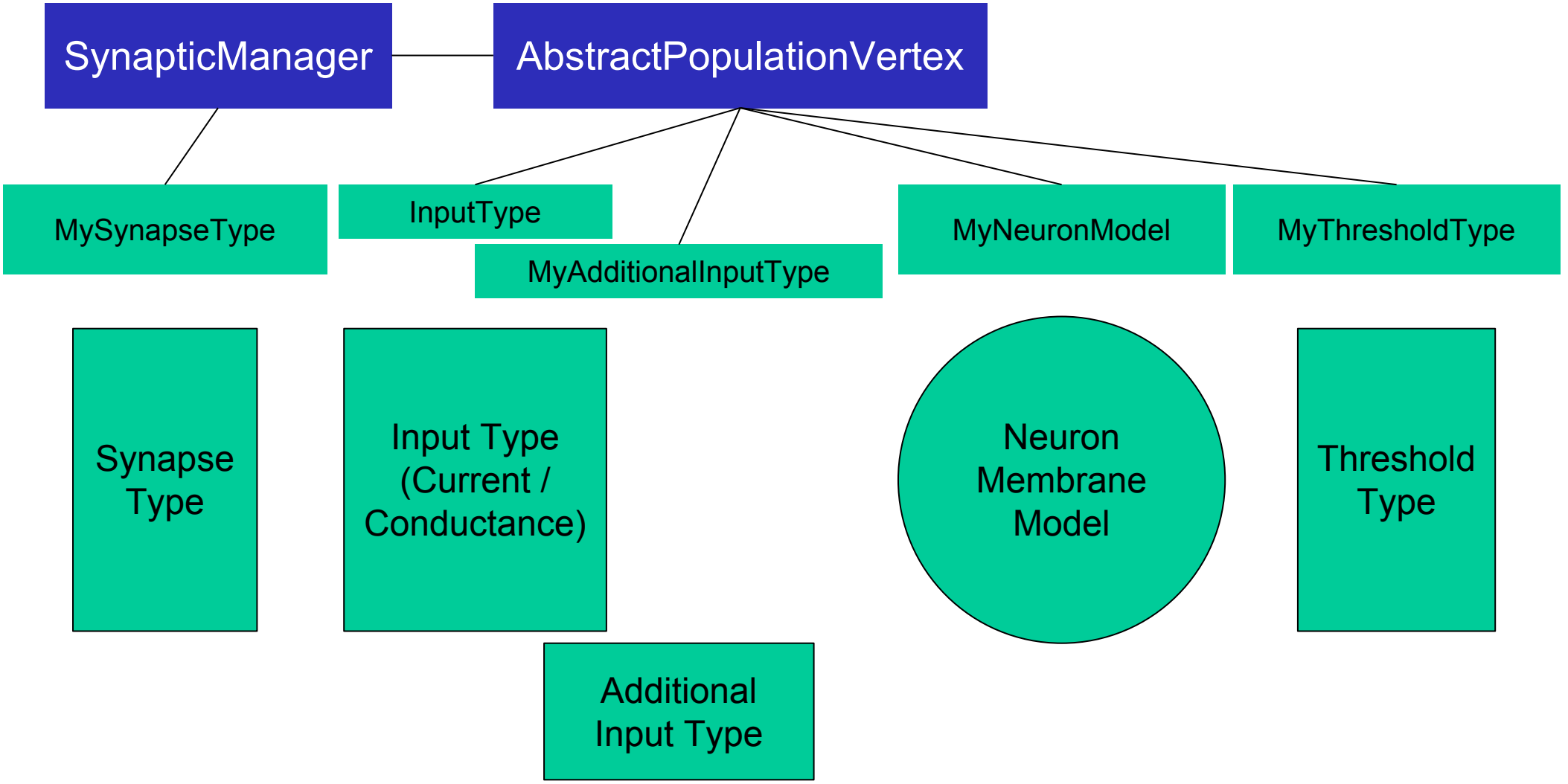
InputType



sPyNNaker Neuron Models - Python



sPyNNaker Neuron Models - Python build



Python Build - Class Definition

```
from spynnaker.pyNN.models.neuron.neuron_models  import NeuronModelIzh
from spynnaker.pyNN.models.neuron.synapse_types  import SynapseTypeExponential
from spynnaker.pyNN.models.neuron.input_types  import InputTypeCurrent
from spynnaker.pyNN.models.neuron.threshold_types  import ThresholdTypeStatic
from spynnaker.pyNN.models.neuron  import AbstractPopulationVertex


# global objects
DEFAULT_MAX_ATOMS_PER_CORE =  255
_IZK_THRESHOLD =  30.0

class IzkCurrExpBase(AbstractPopulationVertex):
```

Python Build

```
class IzkCurrExpBase(AbstractPopulationVertex):

    _model_based_max_atoms_per_core = DEFAULT_MAX_ATOMS_PER_CORE

    default_parameters = {
        'a': 0.02, 'c': -65.0, 'b': 0.2, 'd': 2.0, 'i_offset': 0,
        'u_init': -14.0, 'v_init': -70.0, 'tau_syn_E': 5.0, 'tau_syn_I': 5.0,
        'isyn_exc': 0, 'isyn_inh': 0}
```

Python Build - initializer (1)

```
class IzkCurrExpBase(AbstractPopulationVertex):

...
    def __init__(
            self, n_neurons,
            spikes_per_second=AbstractPopulationVertex.
            none_pynn_default_parameters[ 'spikes_per_second' ],
            ring_buffer_sigma=AbstractPopulationVertex.
            none_pynn_default_parameters[ 'ring_buffer_sigma' ],
            incoming_spike_buffer_size=AbstractPopulationVertex.
            none_pynn_default_parameters[ 'incoming_spike_buffer_size' ],
            constraints=AbstractPopulationVertex.none_pynn_default_parameters[
                'constraints' ],
            label=AbstractPopulationVertex.none_pynn_default_parameters[
                'label' ],
            a=default_parameters[ 'a'], b=default_parameters[ 'b'],
            c=default_parameters[ 'c'], d=default_parameters[ 'd'],
            i_offset=default_parameters[ 'i_offset'],
            u_init=default_parameters[ 'u_init'],
            v_init=default_parameters[ 'v_init'],
            tau_syn_E=default_parameters[ 'tau_syn_E'],
            tau_syn_I=default_parameters[ 'tau_syn_I'],
            isyn_exc=default_parameters[ 'isyn_exc'],
            isyn_inh=default_parameters[ 'isyn_inh']):


        neuron_model = NeuronModelIzh(
            n_neurons, a, b, c, d, v_init, u_init, i_offset)
        ...
```

Python Build - initializer (2)

```
class IzkCurrExpBase(AbstractPopulationVertex):

...
    def __init__(
        ...
            isyn_exc=default_parameters[ 'isyn_exc'],
            isyn_inh=default_parameters[ 'isyn_inh']):

        neuron_model = NeuronModelIzh(
            n_neurons, a, b, c, d, v_init, u_init, i_offset)
        synapse_type = SynapseTypeExponential(
            n_neurons, tau_syn_E, tau_syn_I, isyn_exc, isyn_inh)
        input_type = InputTypeCurrent()
        threshold_type = ThresholdTypeStatic(n_neurons, _IZK_THRESHOLD)

        AbstractPopulationVertex.__init__(
            self, n_neurons=n_neurons, binary= "IZK_curr_exp.aplx", label=label,
            max_atoms_per_core=IzkCurrExpBase._model_based_max_atoms_per_core,
            spikes_per_second=spikes_per_second,
            ring_buffer_sigma=ring_buffer_sigma,
            incoming_spike_buffer_size=incoming_spike_buffer_size,
            model_name= "IZK_curr_exp", neuron_model=neuron_model,
            input_type=input_type, synapse_type=synapse_type,
            threshold_type=threshold_type, constraints=constraints)
```

Python Build - max atoms

```
class IzkCurrExpBase(AbstractPopulationVertex):
    ...

    @staticmethod
    def set_model_max_atoms_per_core(new_value):
        IzkCurrExpBase._model_based_max_atoms_per_core = new_value


    @staticmethod
    def get_max_atoms_per_core():
        return IzkCurrExpBase._model_based_max_atoms_per_core
```

sPyNNaker Neuron Models - Python Build

```
class MyModelCurrExpBase(AbstractPopulationVertex):

    default_parameters = {
        'my_param': 1.0,
        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_thresh': -50.0
        'isyn_exc': 0.0, 'isyn_inh': 0.0
    }

    def __init__(
            self, n_neurons, my_param=default_parameters['my_param'],
            tau_syn_E=default_parameters['tau_syn_E'],
            Tau_syn_i=default_parameters['tau_syn_I'],
            v_thresh=default_parameters['v_thresh'],
            isyn_exc=default_parameters['isyn_exc'],
            isyn_inh=default_parameters['isyn_inh']):

        AbstractPopulationVertex.__init__(
            self, n_neurons=n_neurons,
            ...
            neuron_model=MyNeuronModel(n_neurons, my_param),
            input_type=InputTypeCurrent(),
            synapse_type=SynapseTypeExponential(
                n_neurons, tau_syn_I, tau_syn_E, isyn_exc, isyn_inh),
            threshold_type=ThresholdTypeStatic(n_neurons, v_thresh),
            additional_input=None
            model_name="MyModelCurrExpBase",
            binary="my_model_curr_exp.aplx",
        )
```

Python Build - DataHolder (1)

- This is only required since version 0.8 of PyNN

```
from spynnaker.pyNN.models.neuron  import AbstractPopulationVertex
from spynnaker8.utilities  import DataHolder
from spynnaker.pyNN.models.neuron.builds  import IzkCurrExpBase


class IzkCurrExpDataHolder(DataHolder):
    def __init__(
        self,

        spikes_per_second=AbstractPopulationVertex.
        none_pynn_default_parameters['spikes_per_second'],

        ring_buffer_sigma=AbstractPopulationVertex.
        none_pynn_default_parameters['ring_buffer_sigma'],

        incoming_spike_buffer_size=AbstractPopulationVertex.
        none_pynn_default_parameters['incoming_spike_buffer_size'],

        constraints=AbstractPopulationVertex.none_pynn_default_parameters[
            'constraints'],

        label=AbstractPopulationVertex.none_pynn_default_parameters[
            'label'],
```

Python Build - DataHolder (2)

- This is only required since version 0.8 of PyNN

```
from spynnaker.pyNN.models.neuron  import AbstractPopulationVertex
from spynnaker8.utilities  import DataHolder
from spynnaker.pyNN.models.neuron.builds  import IzkCurrExpBase


class IzkCurrExpDataHolder(DataHolder):
    def __init__(
...
        a=IzkCurrExpBase.default_parameters[ 'a'],
        b=IzkCurrExpBase.default_parameters[ 'b'],
        c=IzkCurrExpBase.default_parameters[ 'c'],
        d=IzkCurrExpBase.default_parameters[ 'd'],
        i_offset=IzkCurrExpBase.default_parameters[ 'i_offset'],
        u_init=IzkCurrExpBase.default_parameters[ 'u_init'],
        v_init=IzkCurrExpBase.default_parameters[ 'v_init'],
        tau_syn_E=IzkCurrExpBase.default_parameters[ 'tau_syn_E'],
        tau_syn_I=IzkCurrExpBase.default_parameters[ 'tau_syn_I'],
        isyn_exc=IzkCurrExpBase.default_parameters[ 'isyn_exc'],
        isyn_inh=IzkCurrExpBase.default_parameters[ 'isyn_inh']):
    DataHolder.__init__(
        self,
        {'spikes_per_second': spikes_per_second,
          'ring_buffer_sigma': ring_buffer_sigma,
          'incoming_spike_buffer_size': incoming_spike_buffer_size,
          'constraints': constraints, 'label': label, 'a': a, 'b': b,
          'c': c, 'd': d, 'i_offset': i_offset, 'u_init': u_init,
          'v_init': v_init, 'tau_syn_E': tau_syn_E, 'tau_syn_I': tau_syn_I,
          'isyn_exc': isyn_exc, 'isyn_inh': isyn_inh})
```

Python Build - DataHolder (3)

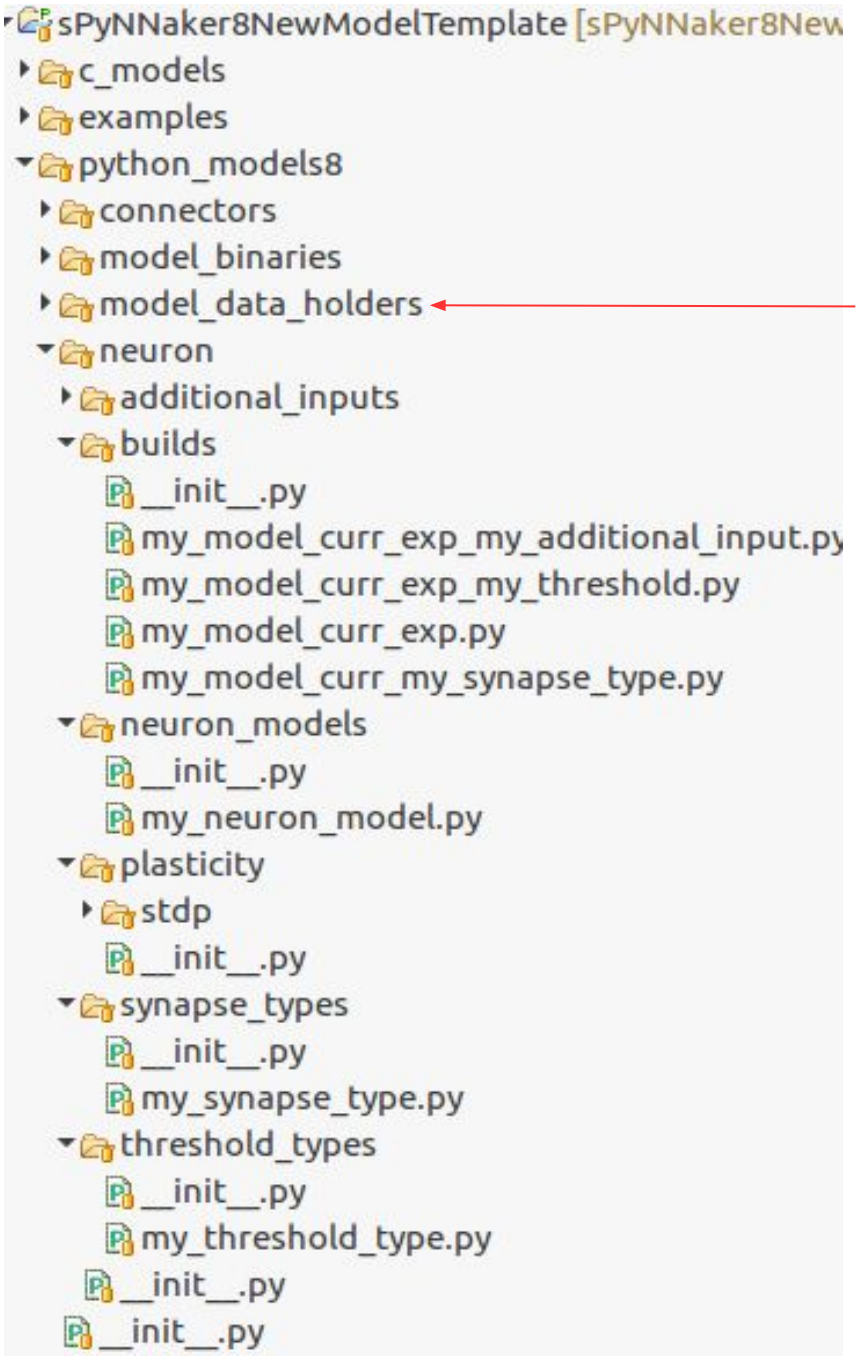
- This is only required since version 0.8 of PyNN

```
from spynnaker.pyNN.models.neuron  import AbstractPopulationVertex
from spynnaker8.utilities  import DataHolder
from spynnaker.pyNN.models.neuron.builds  import IzkCurrExpBase


class IzkCurrExpDataHolder(DataHolder):

...

    @staticmethod
    def build_model():
        return IzkCurrExpBase
```

New Model Template

C code template

Python code template

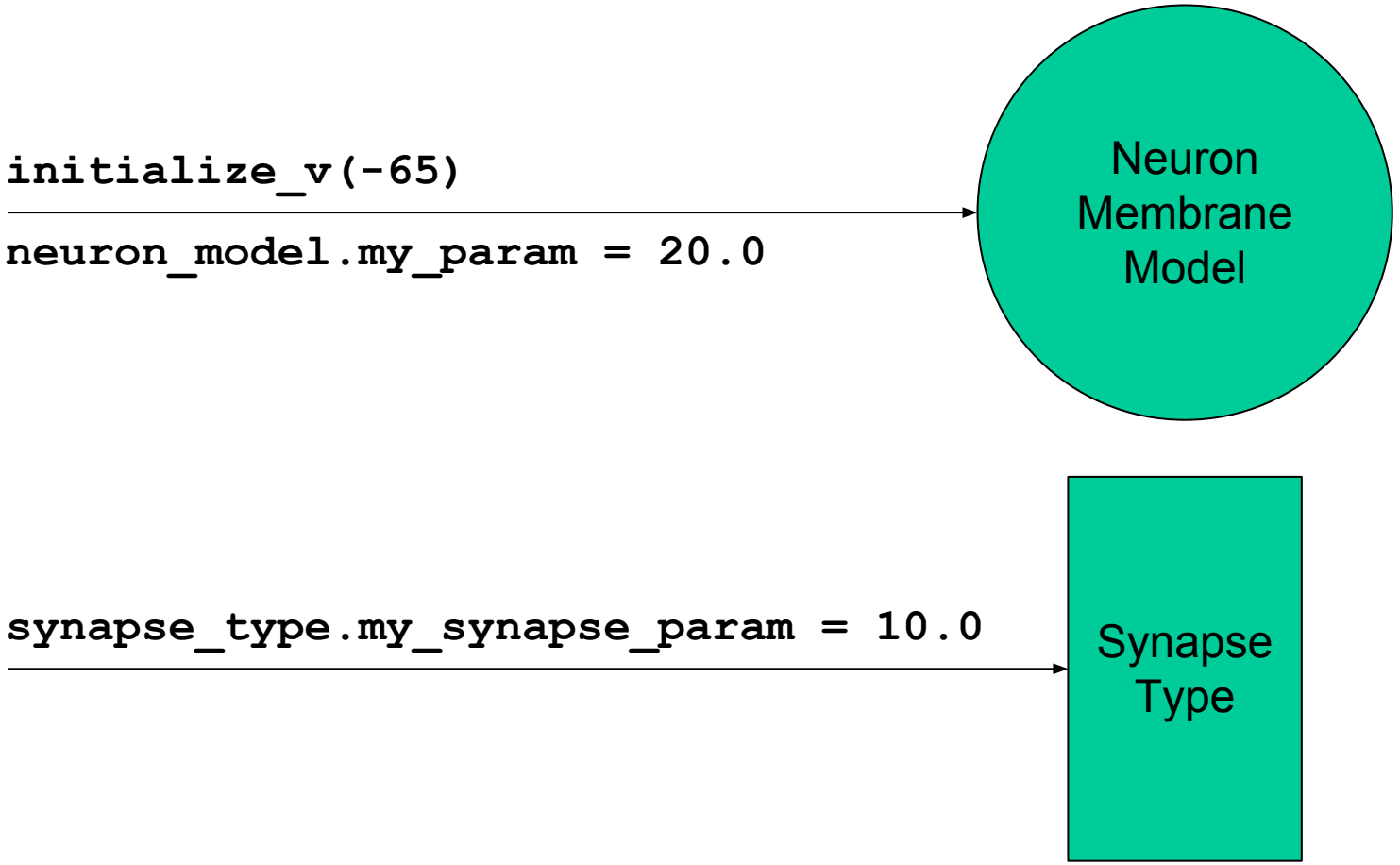


PyNN 0.8

sPyNNaker Neuron Models - PyNN

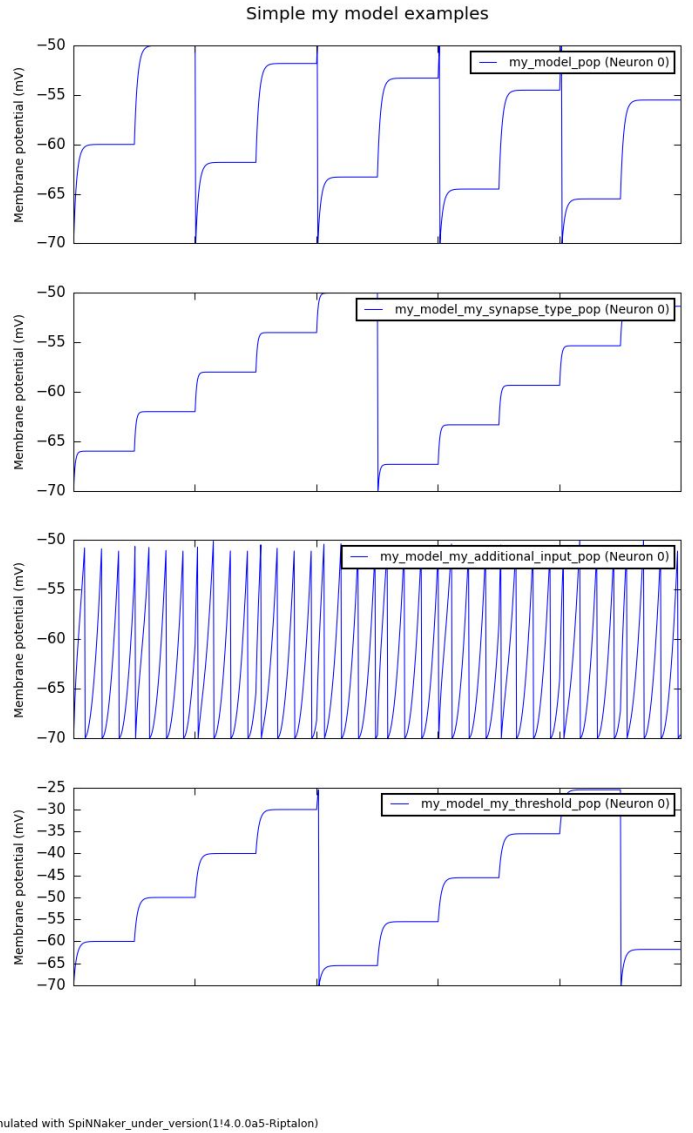
PyNN Script

```
pop.initialize(v=-65.0)   # initialize("v", -65.0)

pop.set(my_param=20.0)   # set("my_param", 20.0)

pop.set(my_synapse_param=10.0)
```



Using your model with PyNN

```
import pyNN.spiNNaker as p  (Check this...!)
from python_models8.model_data_holders.my_model_curr_exp_data_holder \
    import MyModelCurrExpDataHolder as My_Model_Curr_Exp

# set parameters
time_step = 1.0
weight = 2.0
spike_times = range( 0, run_time, 100)

p.setup(time_step)

spikeArray = {"spike_times": spike_times}
Input_pop = p.Population(
    1, p.SpikeSourceArray(**spikeArray), label= "input")

myModelCurrExpParams = {
    "my_parameter": -70.0,
    "i_offset": i_offset
}
my_model_pop = p.Population(
    1, My_Model_Curr_Exp(**myModelCurrExpParams),
    label="my_model_pop")
p.Projection(
    Input_pop, my_model_pop,
    p.OneToOneConnector(), receptor_type='excitatory',
    synapse_type=p.StaticSynapse(weight=weight))

# etc. etc.
```



Summary

- Define a new neuron model in C (solving the ODE), make sure that the parameters are correctly passed to it from Python / PyNN
- Define the different components of the model in a similar manner
- If a component function you require is not available in the NewModelTemplate, our advice is to copy the code in sPyNNaker and sPyNNaker8 and edit it

- Coming soon: a rewrite of NewModelTemplate to allow the user to define their neuron model in a more independent manner from its components

sPyNNaker Neuron Models - Lab

http://spinnakermanchester.github.io/spynnaker/4.0.0/PyNNOnSpiNNakerExtensions.html

or

http://spinnakermanchester.github.io

Running PyNN Scripts …. (1st link)

Extending sPyNNaker with New Neuron … (6th link)

or

See your paper version