

# BrainScaleS Workshop

4th HBP School

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## First Section

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# Analog Neuromorphic Hardware

1

observations



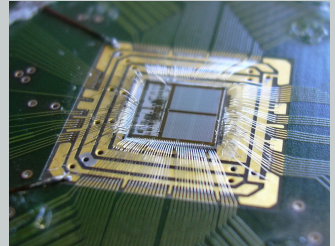
2

mathematical model

$$C \frac{dV}{dt} = -g_L(V - E_L) + I_{\text{syn}}(t)$$

3

hardware realization



# Roadmap

2004

## Spikey

- single chip system
- 384 LIF neurons

2010

## HICANN

- 180 nm CMOS
- 512 AdEx neurons

2015

## 20 Wafer System

- 4 million neurons
- 0.9 billion synapses

2017

## HICANN DLS

- 65 nm CMOS
- PPU:  
integrated processing unit for advanced plasticity

2022

## 500 Wafer System

- 500 million neurons
- 130 billion synapses

<https://neuralensemble.org/docs/PyNN/0.7/api/api-0.7.html>

Look out for:

- `pynn.Population`
- `pynn.Projection`
- `pynn.*Connector`

# Creating (groups of) neurons

Create *populations* of neurons:

```
params = {  
    "v_thresh": -60.0  
}  
neurons = pynn.Population(42, pynn.IF_facets_hardware1, cellparams=params)
```

Get a list of default neuron parameters:

```
print pynn.IF_facets_hardware1.default_parameters
```

# Generating stimuli

Create a stimulus from a spike train:

```
spike_train = np.arange(10.0, 101.0, 10.0)
stimulus = pynn.Population(1, pynn.SpikeSourceArray, {"spike_times": spike_train})
```

There is also a Poisson spike source:

```
poisson_params = {
    "start": 10.0,
    "duration": 100.0,
    "rate": 5.0
}
stimulus = pynn.Population(1, pynn.SpikeSourcePoisson, poisson_params)
```

# Synaptic connections



# Recording observables

## Spike times:

```
neurons.record()  
...  
spikes = neurons.getSpikes()
```

## *Analog* membrane traces:

```
pynn.record_v(neurons[0], "")
```

- only *one* analog-to-digital converter (ADC)  
→ one can record a single neuron at a time

## Tasks

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## Task 1: a single neuron



- create a spike source
- create a single LIF neuron
- connect these two populations with maximum weight
- record spikes and the membrane trace of the stimulated neuron

1. vary the synaptic weight and observe the membrane trace
2. play around with the inter-spike interval of the stimulating spike train
3. observe how the PSPs stack up and eventually cause the neuron to fire

## Task 2: passing spikes