# Adaptive Synapses and Integrate-and-Fire Neurons for a Multi-Chip Selective Attention System

*Elisabetta Chicca, Giacomo Indiveri and Rodney J. Douglas*

Eidgenössische Technische Hochschule Zürich

*Institute of Neuroinformatics, UNIZH/ETH,*
*Winterthurerstrasse 190, CH-8057 Zurich, Switzerland*

## Introduction

**We present measurements from an analog VLSI (Very Large Scale Integrated) chip containing circuits implementing adaptive synapses and leaky Integrate-and-Fire (I&F) neurons.**
**We focus on the behaviour of the synaptic circuit and the effect of the synaptic current on the postsynaptic depolarization.**

## Adaptive Synapses

**Cortical synapses between pyramidal neurons exhibit two types of short-term adaptation mechanisms: facilitation and depression [1]. The mechanism we are interested in is *synaptic depression*, by which the synaptic strength is decreased in response to successive presynaptic action potentials. For constant input firing rate, the steady-state EPSP (excitatory postsynaptic potential) amplitude decreases as a function of the rate [2].**

## The Synaptic circuit

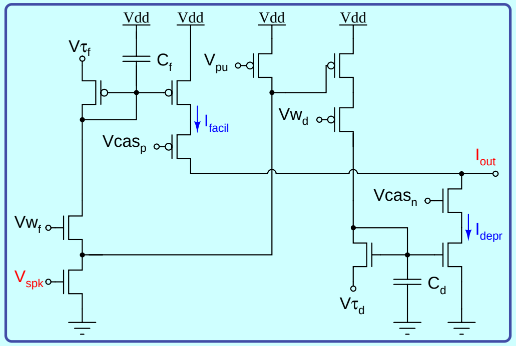


*FIG. 1: Synaptic circuit. The input of the ciruit is the spike signal of the presynaptic neurons. The output current is the sum of facilitating and depressing currents.*

## The Synaptic Strength is Decreased in Response to Successive Presynaptic Action Potentials

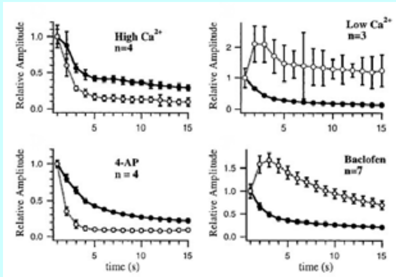


*FIG. 2: Effects of pharmacological manipulation on response of layer 2/3 synapses fo rat primary visual cortex to 20 Hz trains (adapted from [1]).*

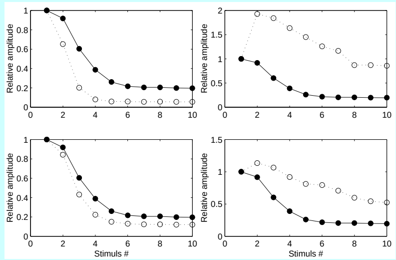


*FIG. 3: Response of VLSI synapse to 20 Hz trains with different parameter values.*

## For Constant Input Firing Rate, the Steady-State EPSP Amplitude Decreases as a Function of the Rate

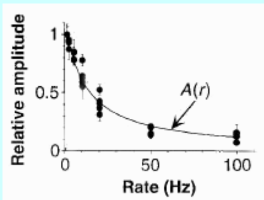


*FIG. 4: The normalized steady-state amplitude of EPSP of cortical neurons at rates from 1 to 100 Hz (adapted from [2]).*

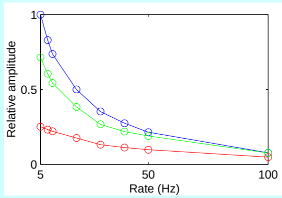


*FIG. 5: The normalized steady-state amplitude of EPSP of silicon neurons at rates from 5 to 100 Hz for different values of bias parameters.*

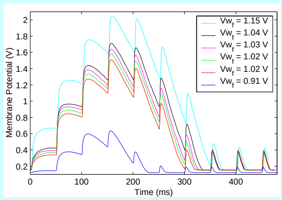


*FIG. 6: Postsynaptic membrane potential in response to 20 Hz trains for different values of the parameter controlling the strength of the facilitating part of the synaptic circuit.*

## Future Work

**Synaptic depression leads to a loss of sensitivity to sustained rates and an increase in the sensitivity to abrupt changes in rate (*dynamic gain control*). This property can be used by a selective attention system to normalize the input coming from different sensory modalities and/or feature detection modules.**
**A new chip currently in fabrication will be used to build a multi-chip selective attention system. The inter and intra-chip connection will be managed using a custom PCI-AER (Peripheral Component Interconnect-Address Event Representation) board.**

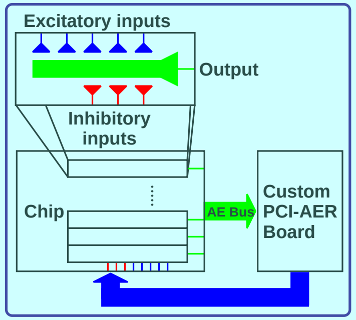


*FIG. 7: Chip architecture and custom PCI board configuration.*

## References

**[1] Varela, J. A., Sen, K., Gibson, J., Fost, J., Abbott, L. F., and Nelson, S. B. (1997). A Quantitative Description of Short-Term Plasticity at Excitatory Synapses in Layer 2/3 of Rat Primary Visual Cortex. *The Journal of Neuroscience*, 17(20): 7926-7940.**

**[2] Abbott, L. F., Varela, J. A., Sen, K., and Nelson, S. B. (1997). Synaptic Depression and Cortical Gain Control. *Science*, (275): 220-224.**