

Neuromorphic Engineering: Biological and silicon retinas

In this part of the block course, you will learn about retinas, both biological and silicon.

The tutorial part will cover the basics of Neuromorphic Engineering, teach you what a transistor is, and then use the structure and function of biological retinas as an example of how silicon retina vision sensors are built.

For its practical exercises, this part will use two neuromorphic chips, the *Physiologist's Friend Chip* (short name *PhysioFriend*), and the *Dynamic Vision Sensor Silicon Retina* (short name *DVS*). The practical work will consist of experiments using these sensors.

Your report on this part of the course should cover the 3 practical experiments and answer the questions at the end of this document.

Reading

For reading we will provide 2 articles.

1. **“A silicon visual system as a model animal”**. T. Delbruck, S.C. Liu. (2004). *Vision Research*, vol. 44, issue 17, pp. 2083-2089. – This paper shows you how the physiologist's friend chip works.
2. **“Neuromorphic Sensory Systems”**, T. Delbruck and S.C. Liu (2010) *Current Opinions on Neurobiology* — This paper is about silicon retinas and cochleas.

Practical work

We will have 3 sets of experimental setups:

1. (Lecture room or INI Foyer) Physiologist's Friend Chips for determining the receptive fields by plotting them on a tangent screen, like you did with the simulation.
2. (dungeon) DVS128 event-based silicon retinas.

Schedule

Morning of first day: Lecture sessions and reading to prepare for practical sessions of next day

Morning of second day: Practical works, sessions 1

Afternoon of second day: Practical work session 3, quiz.

Report

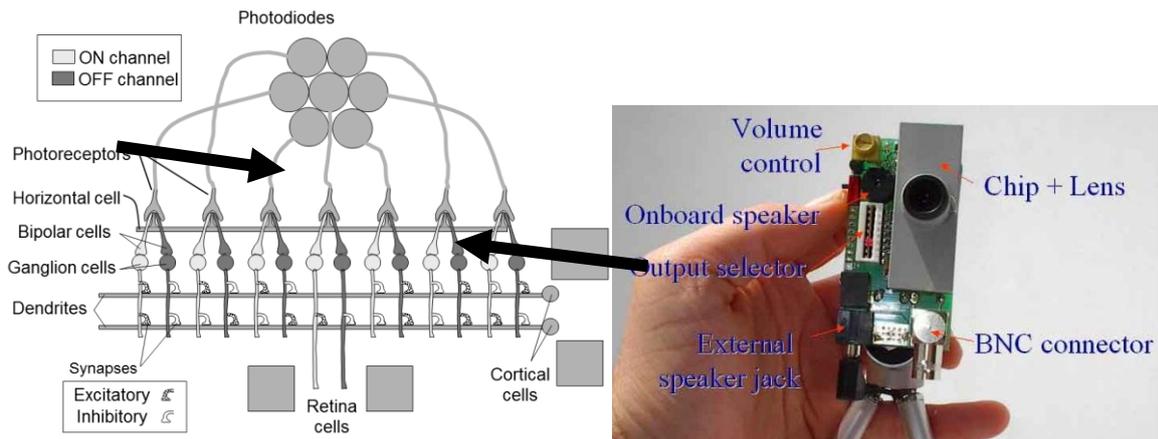
Please hand in a group report (**make sure all names of people involved are on the report**) on your practical work, including answers to the questions in the practical works and at the end of this document. **Your report should be handed in after the weekend, before the next block course block.**

You will also receive a quiz to be completed during the last hour of the final day, which you must complete without use of notes or handouts and hand in after one hour.

Practical work 1: Characterizing physiologist friend chip cells

Your aim here will be to learn about the architecture of the Physiologist's Friend Chip and to determine the cell types and receptive fields of 4 spiking cells.

The illustrations below show the architecture of the chip and the controls and outputs on the board. See the paper about the chip for more information.



Report

In your report, explain the receptive fields of the cells numbered **3 and 4**. You should identify the ON and OFF regions of each receptive field and quantify how large they are in degrees. To get the degrees, measure the size S_{cm} in cm of the receptive field, the distance from the stimulus to the chip d_{cm} in cm, and compute

$$S_{\text{deg}} = 57 S_{\text{cm}} / d_{\text{cm}} .$$

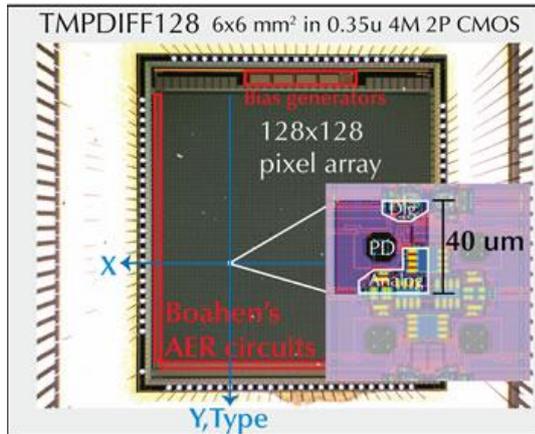
Also your report should explain the following principles:

1. The concept of a *receptive field*.
2. The effect of photoreceptor adaptation to background light intensity and photoreceptor gain control. To explain the response, you can sketch the photoreceptor response in various ways, e.g. as a function of time, log intensity, or temporal frequency.
3. Why the center-surround retinal receptive fields respond transiently to overall changes in the brightness of the scene; for instance, when you listen to the ON center ganglion cell, why does it make a burst of ON spikes when you suddenly change the stimulus from uniform black to uniform white?
4. Complementary channels and rectification¹ of signed quantities into e.g. ON/OFF channels as a mechanism for representing signed quantities in the nervous system.
5. Center-surround responses as a mechanism for representing contrast.

Practical work 2: Learning to use the Dynamic Vision Sensor silicon retina to record a slow motion video

In this experiment we have set up several stations in the dungeon with the DVS that you can observe and record on a computer over a USB interface. This device is explained on siliconretina.ini.uzh.ch and is shown here:

¹ *Rectification* here means to convert signed quantities into absolute value positive unsigned quantities.



Each retina has 128x128 pixels and the spike output addresses are captured by a computer and displayed for you in the jAER software. This chip is an Address-Event Representation (AER) chip which means that the output of the camera is a stream of time-stamped address-events, which are active pixel addresses. The pixels respond to movement, or more specifically, to *temporal contrast*. Each spike means that the log intensity has changed by a threshold amount T since the last event from that pixel.

To start the viewer that shows the output of the DVS, open a terminal and enter “jAERViewer.sh” to the prompt. The retina output will then be shown in a window, where you can start and stop recording via the “Start Logging” button. The operation of the viewer will be demonstrated in class first.

Make your own slow-motion video of something moving quickly, for example, a pen dropping onto the table, a spinning coin, a pencil breaking in half, a balloon popping. Play back the video using the “Flex time” mode (constant event rate), rather than constant time slice. What does flex-time playback do when playing back such a recording?

1. When making a recording, it is very helpful to make sure the lens is properly focused to be as sharp as possible and the aperture should be as open as possible to maximum the amount of light.
2. If you are getting too few events, then you can try to reduce the event threshold – hit the *Biases* button at the lower left and adjust the event threshold slider.
3. Remember the single most important maxim of machine vision: “Lighting, lighting lighting.” If you don’t have the right lighting, forget it.

Report

For your report, you should explain how the DVS pixel works by drawing the schematic and explaining, how it works, and how it mimics the transient pathway in a very simplified biological retina.

From the following work, please email ” to tobi@ini.phys.ethz.ch or pass otherwise (e.g. by USB stick) to Tobi your best recording named “<yourname>-2011.aedat”, for example “tobidelbruck-2011.aedat”:

Block course improvements

Please provide concrete suggestions for improving this part of the block course? For example, is the material too difficult or too easy? What part did you enjoy the most? The least? What part will be most useful to you? Least useful? What words were unclear and need more definition? What material needs more background to be presented?

Final quiz

You will have 1 hour to answer without any notes as best as possible the questions that will be handed to you.

Grade

Your grade in this section will be based on both the combined reports and your answers to the quiz.