The Physiologist's FriendChip

A product of the Institute of Neuroinformatics

"The only FriendChip you'll ever need"


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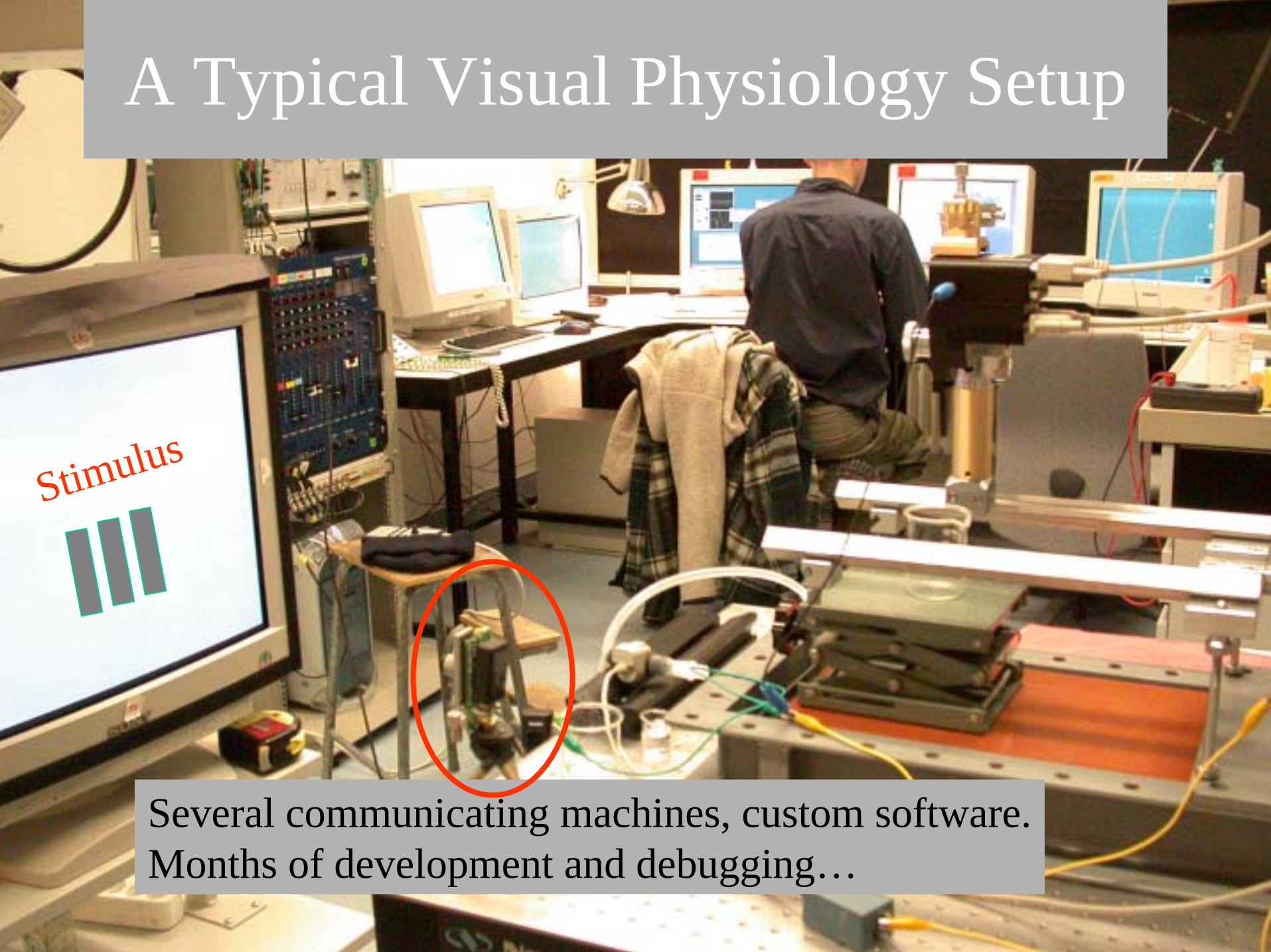
Jorg Kramer

A Typical Visual Physiology Setup

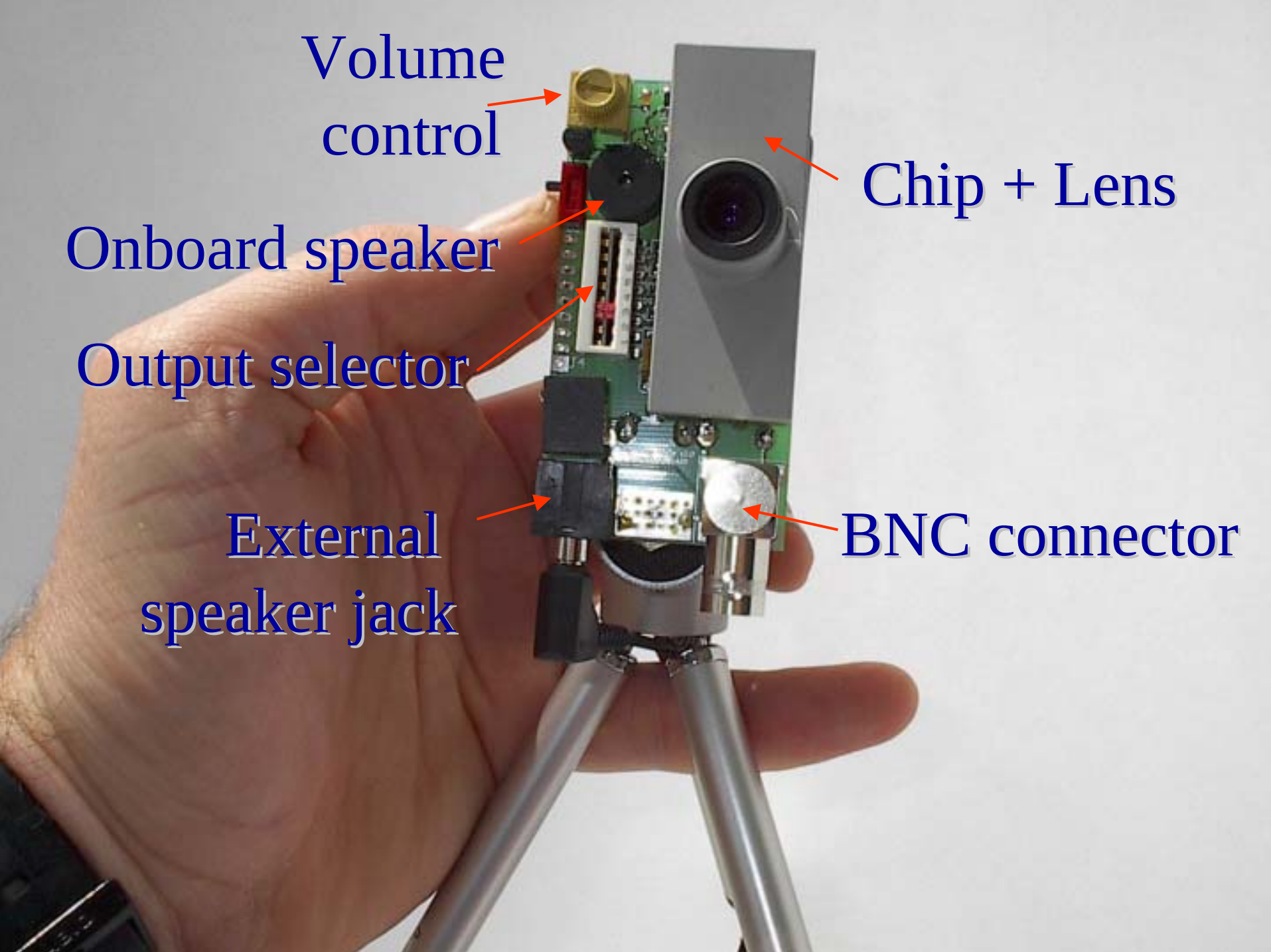


Several communicating machines, custom software.
Months of development and debugging…

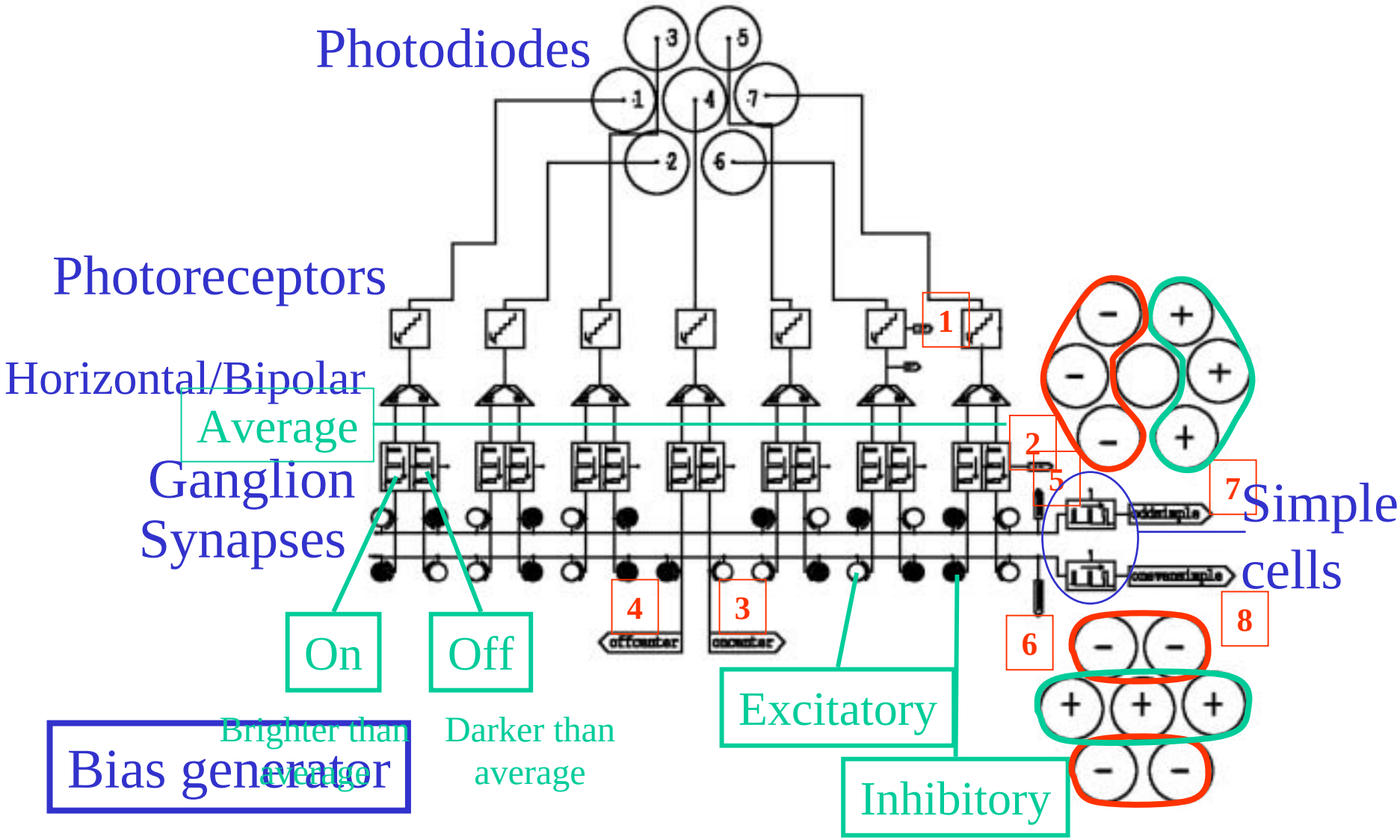
Goal

To make a *practical* chip that acts as a *substitute animal* for experiment design or demonstration.

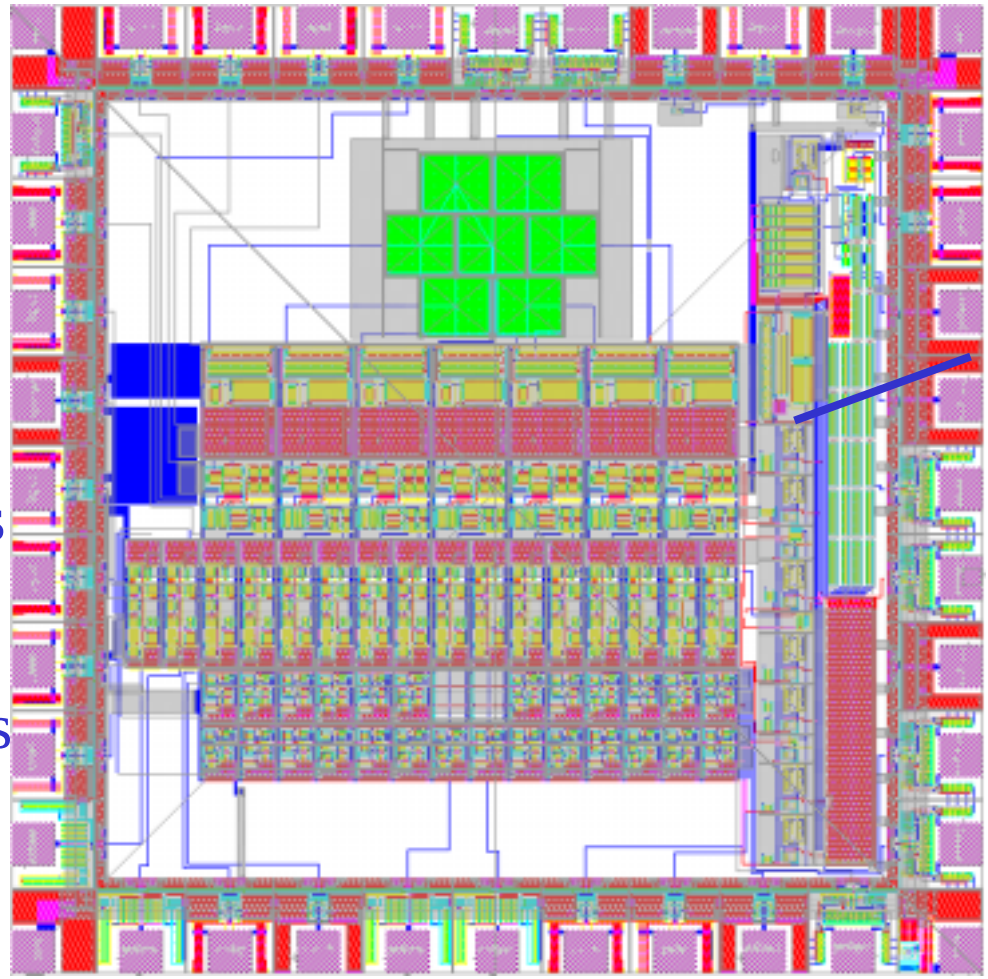
- It should provide spiking neurons from retina and early visual cortex.
- It should be plug and play:
  - battery power
  - no computer
  - no knobs.


Volume control
Chip + Lens
Onboard speaker
Output selector
External speaker jack
BNC connector

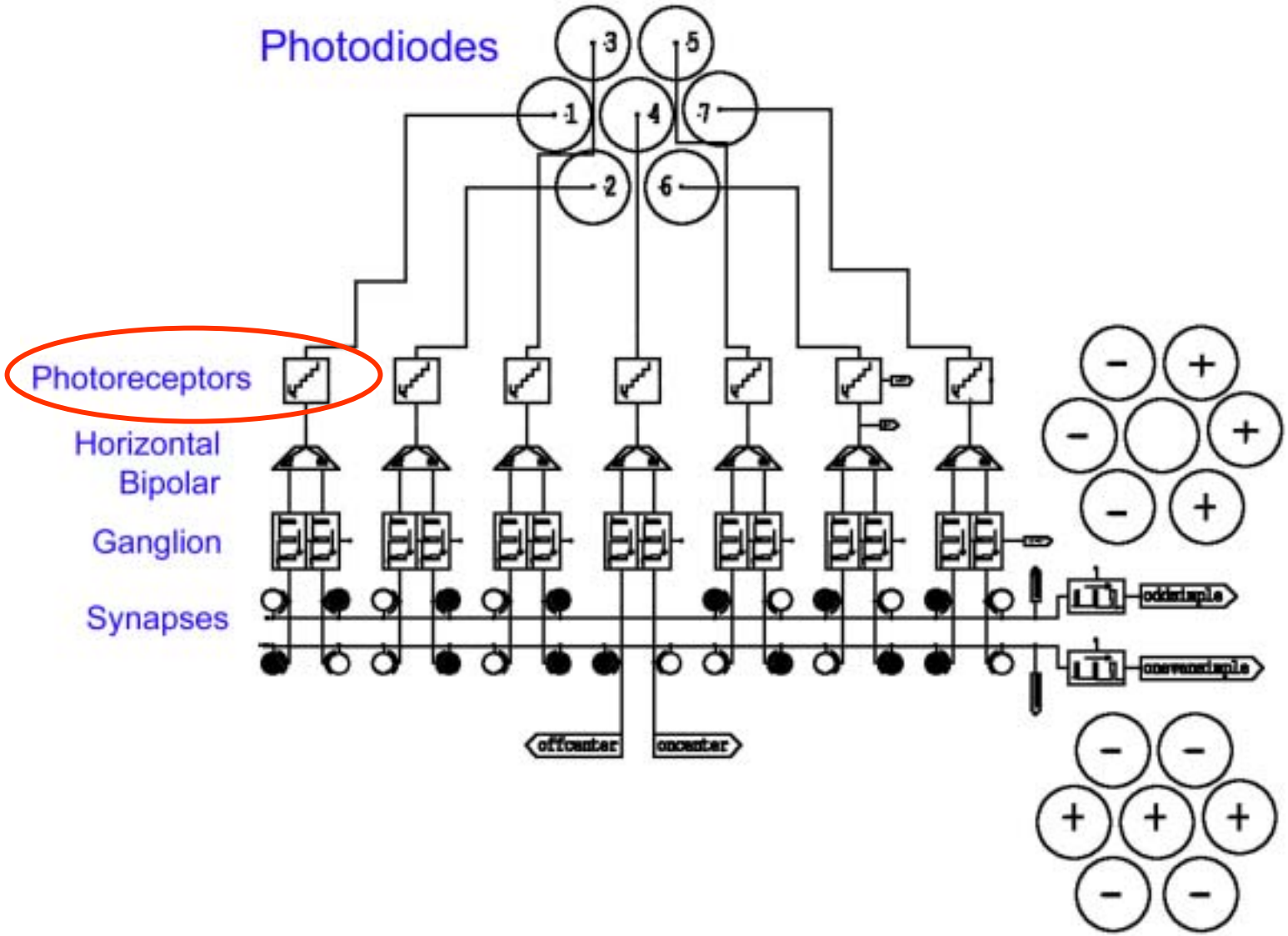
Chip schematic



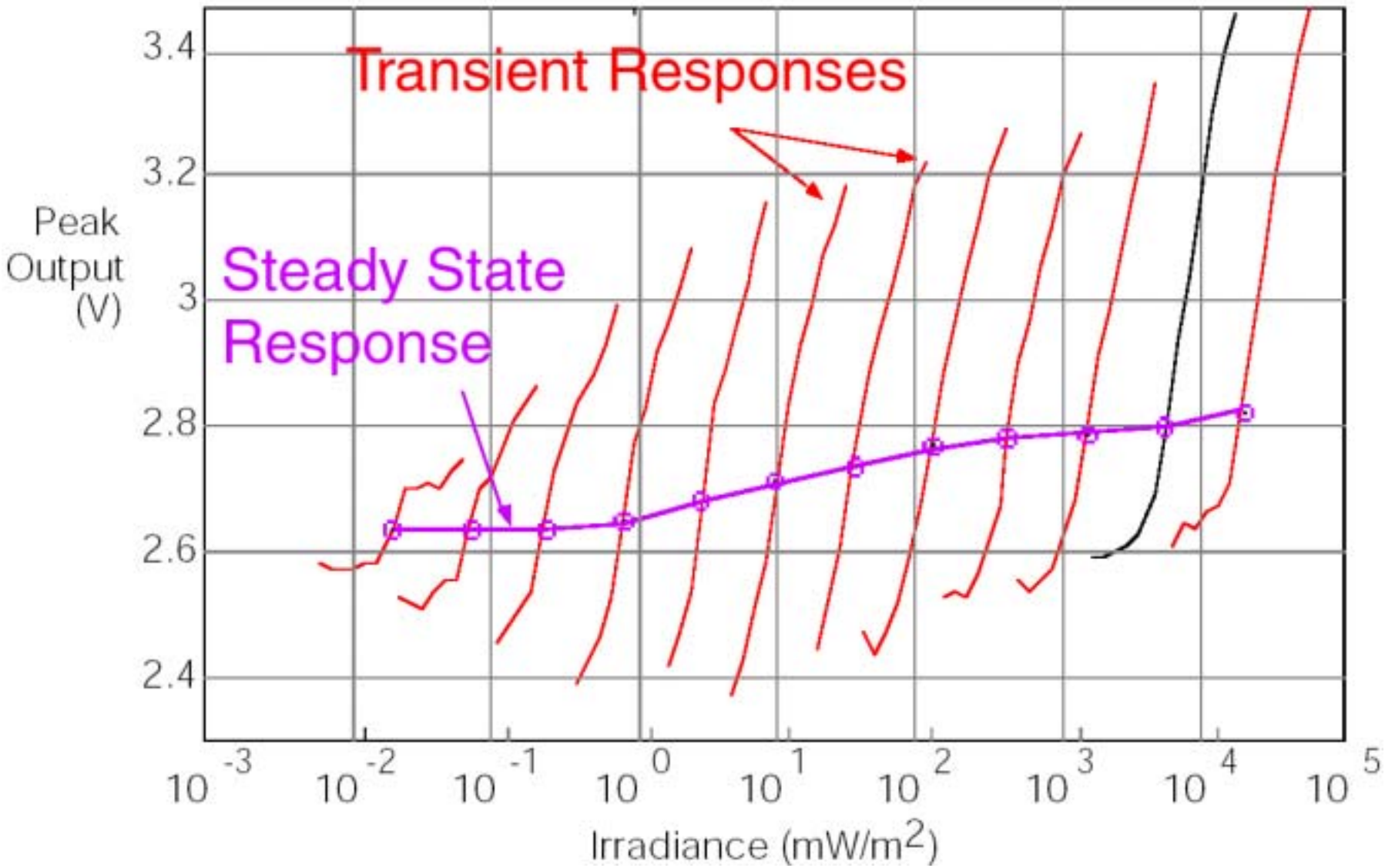
Layout


Photodiodes
Photoreceptors
Bipolar/Horizontal cells
Ganglion & Simple cells
Synapses
Biases
2.2mm

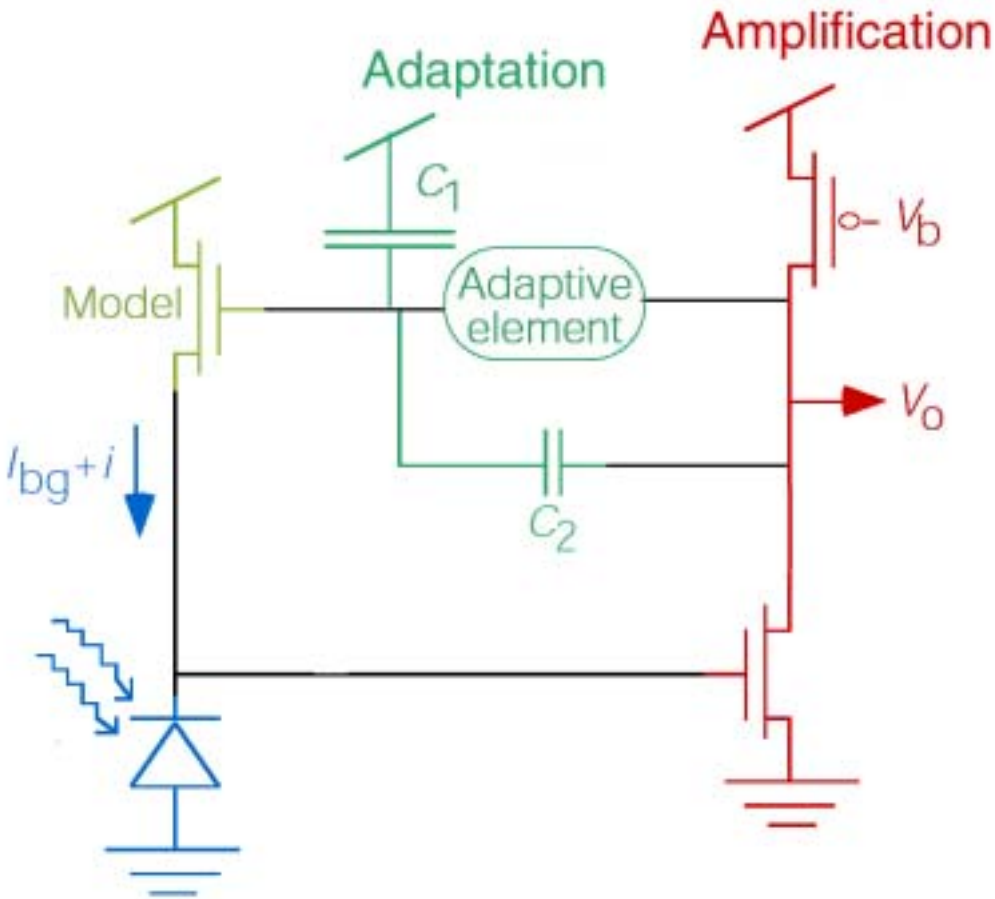
Photoreceptor layer

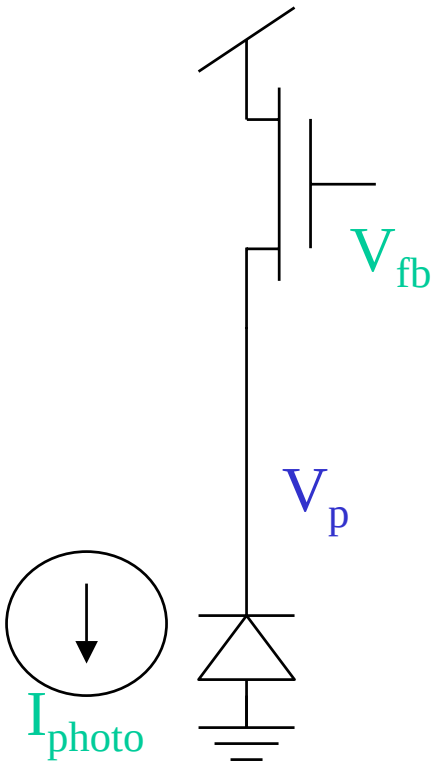


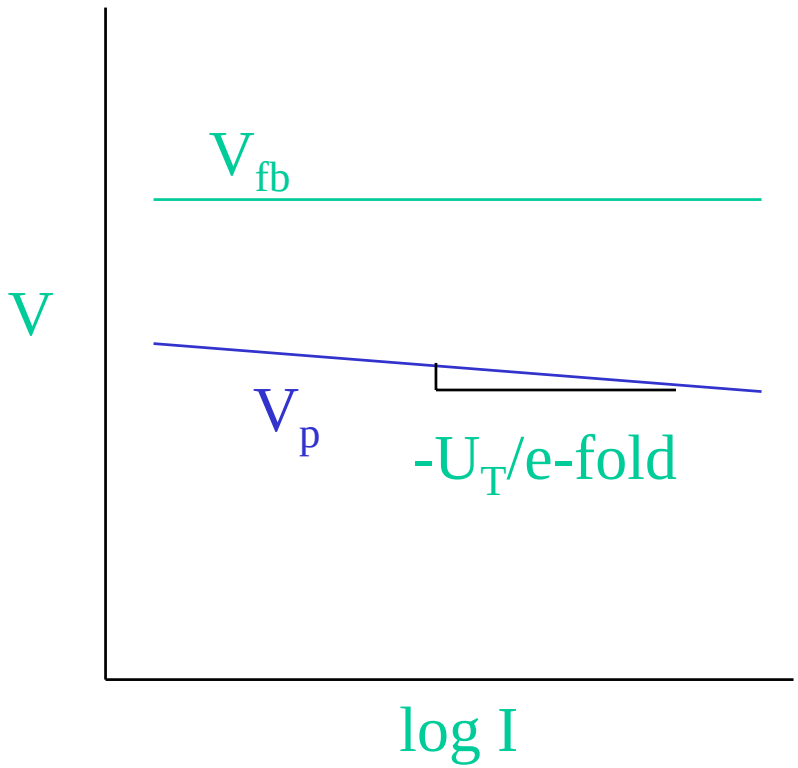
Photoreceptor has low DC gain, high transient gain



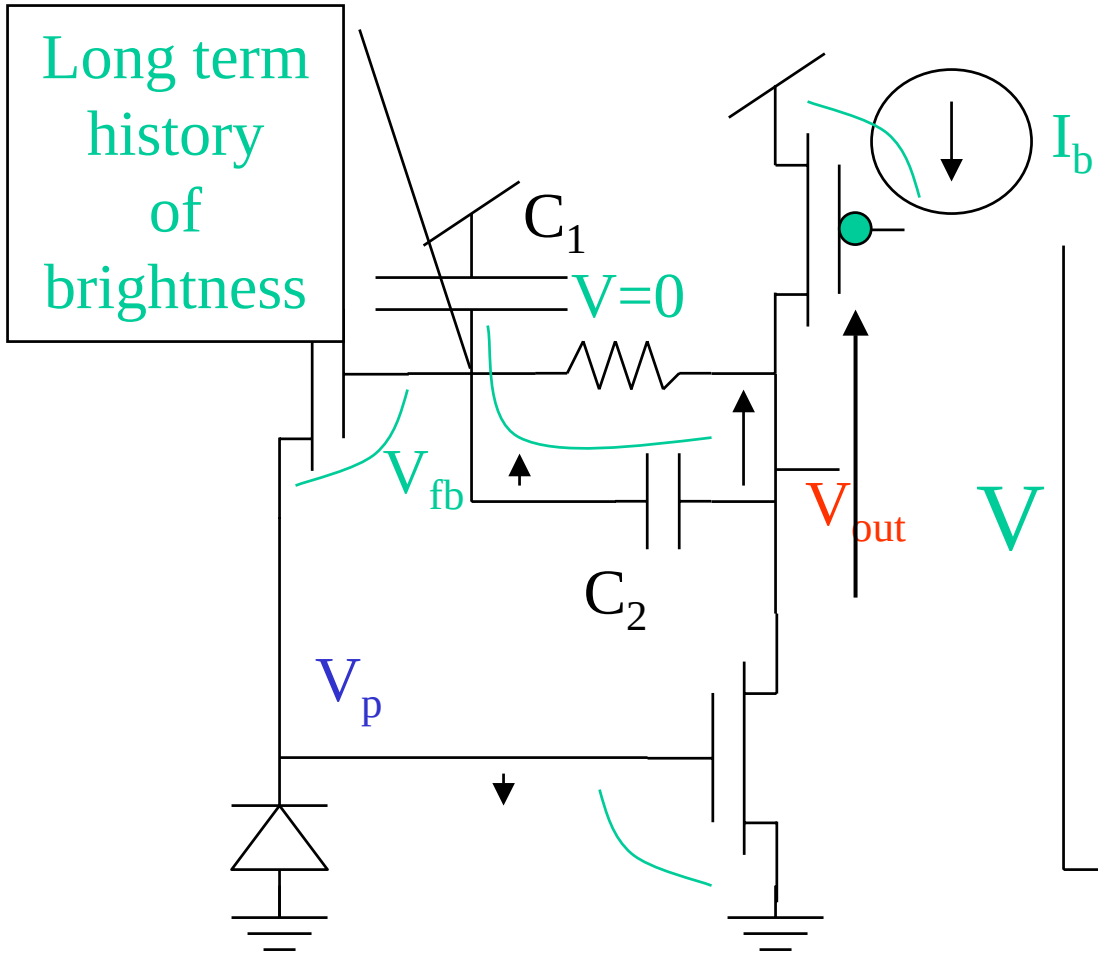
Adaptive Photoreceptor Circuit

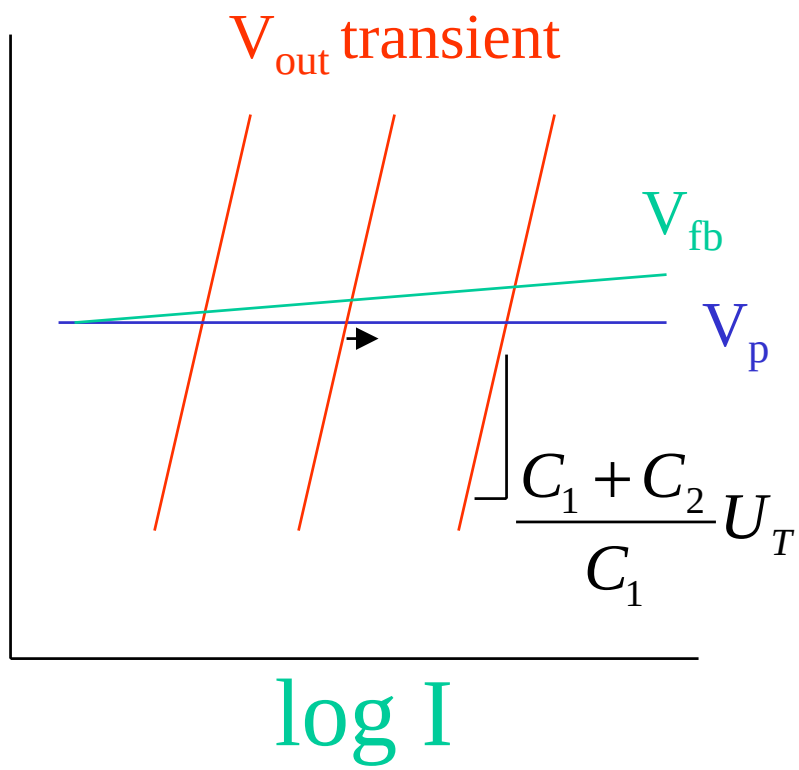



V_{fb}
V_p
I_{photo}


V_{fb}
V
V_p
$-U_T$/e-fold
log I

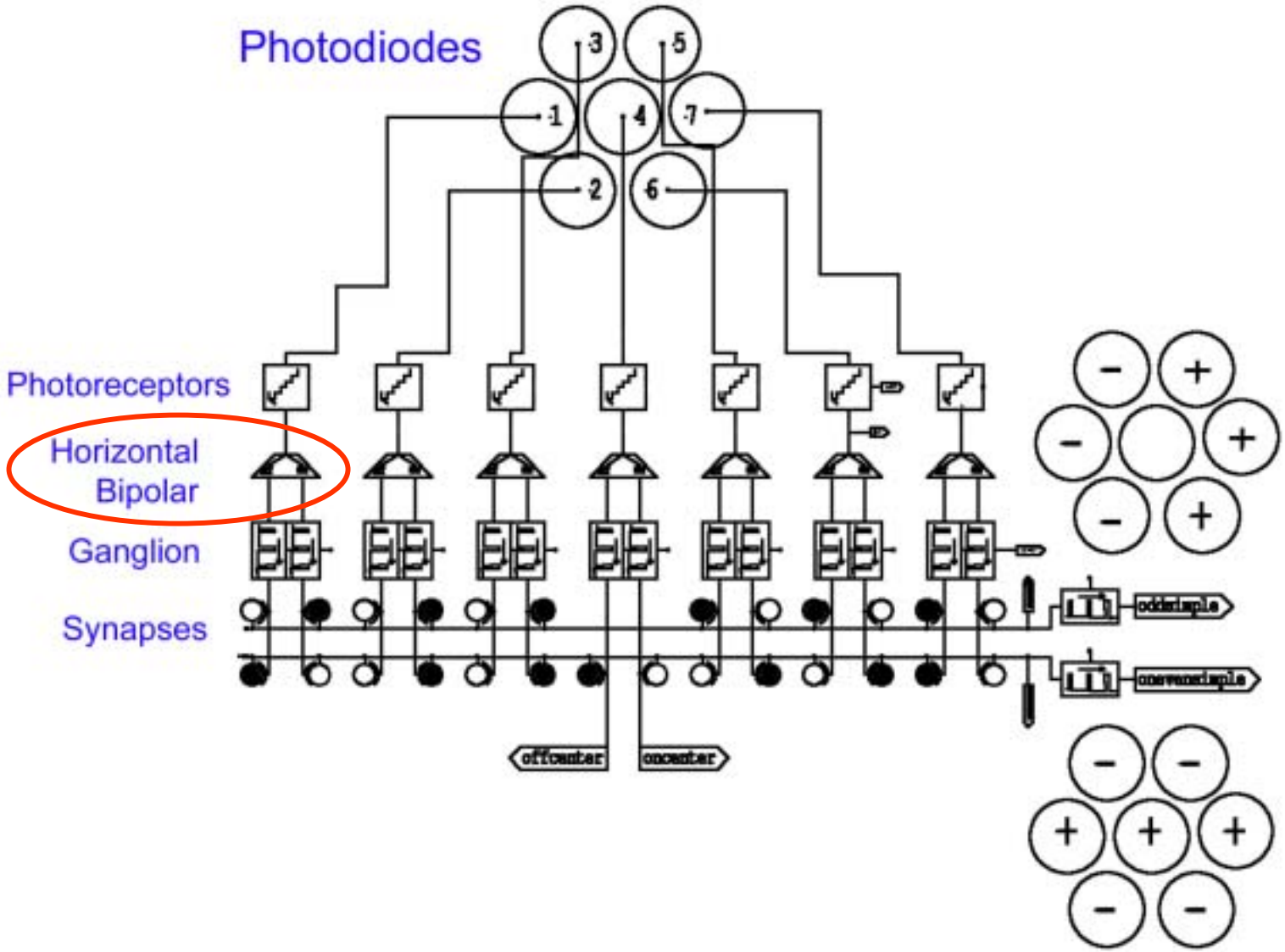
Long term history of brightness





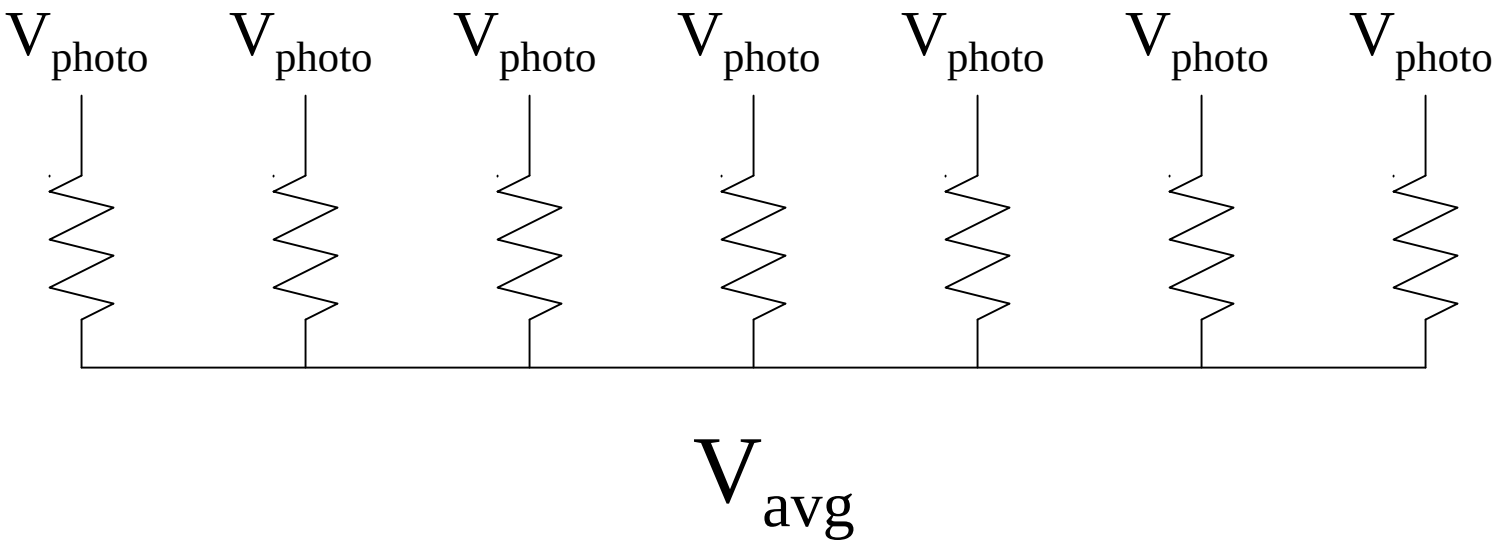
In steady state (DC)

Bipolar and Horizontal Layer



Horizontal cell

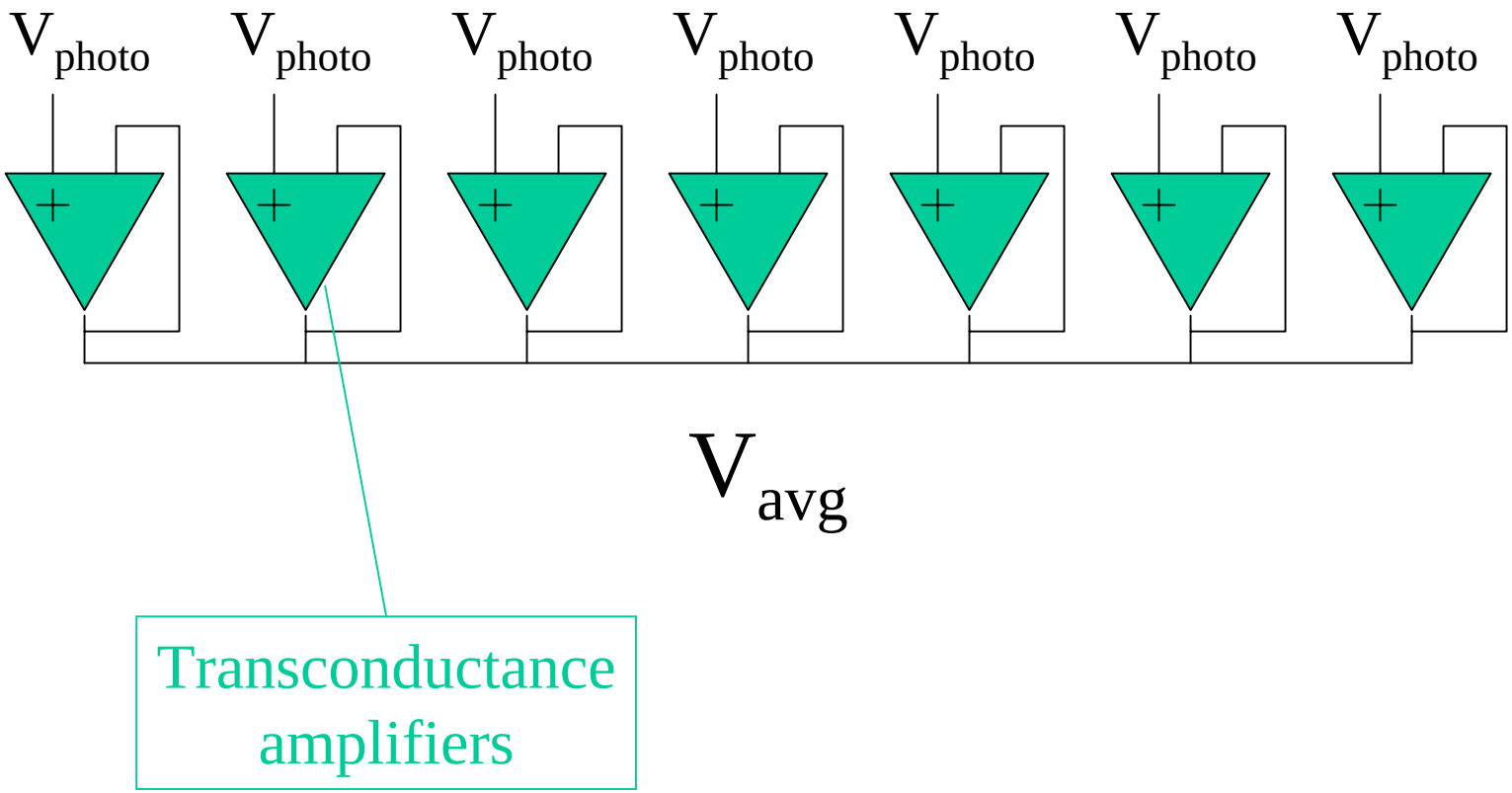
Averages photoreceptor output



Horizontal cell

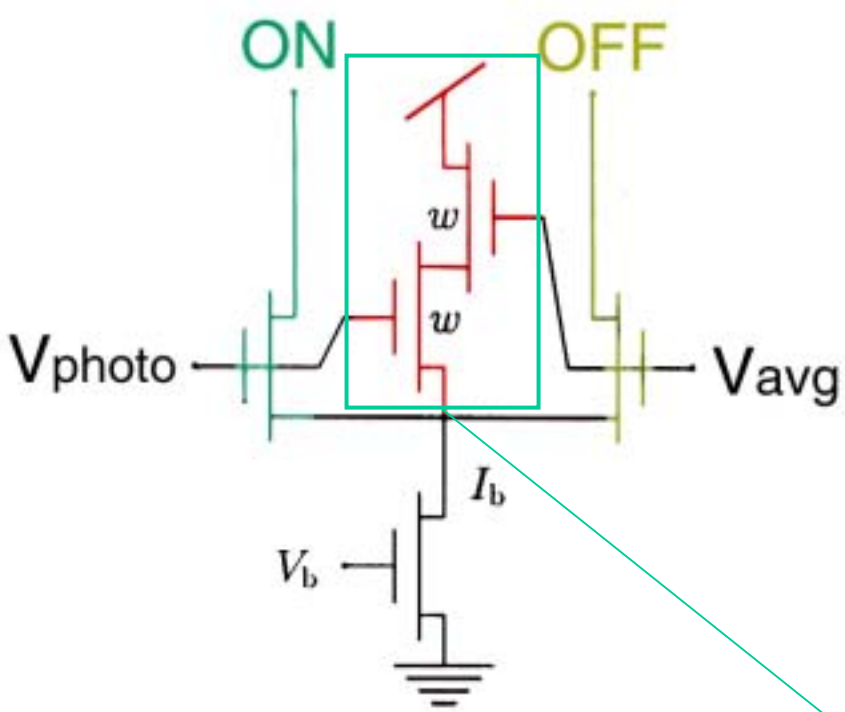
Averages photoreceptor output

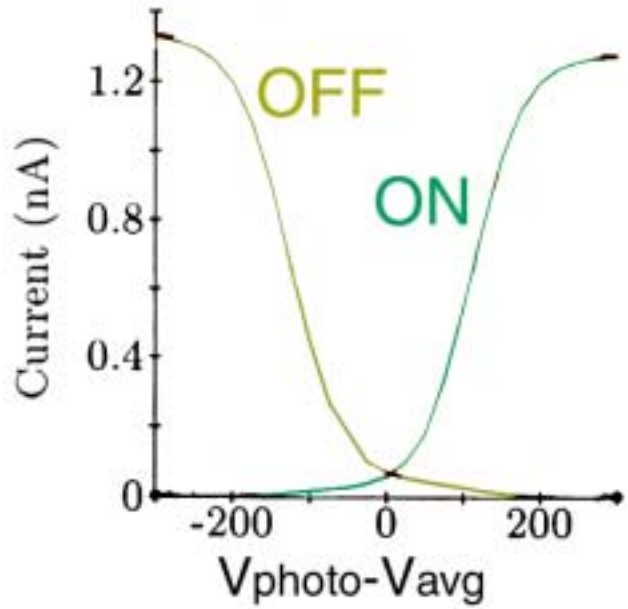
Using Deweerth's follower aggegrator



Bipolar Cell

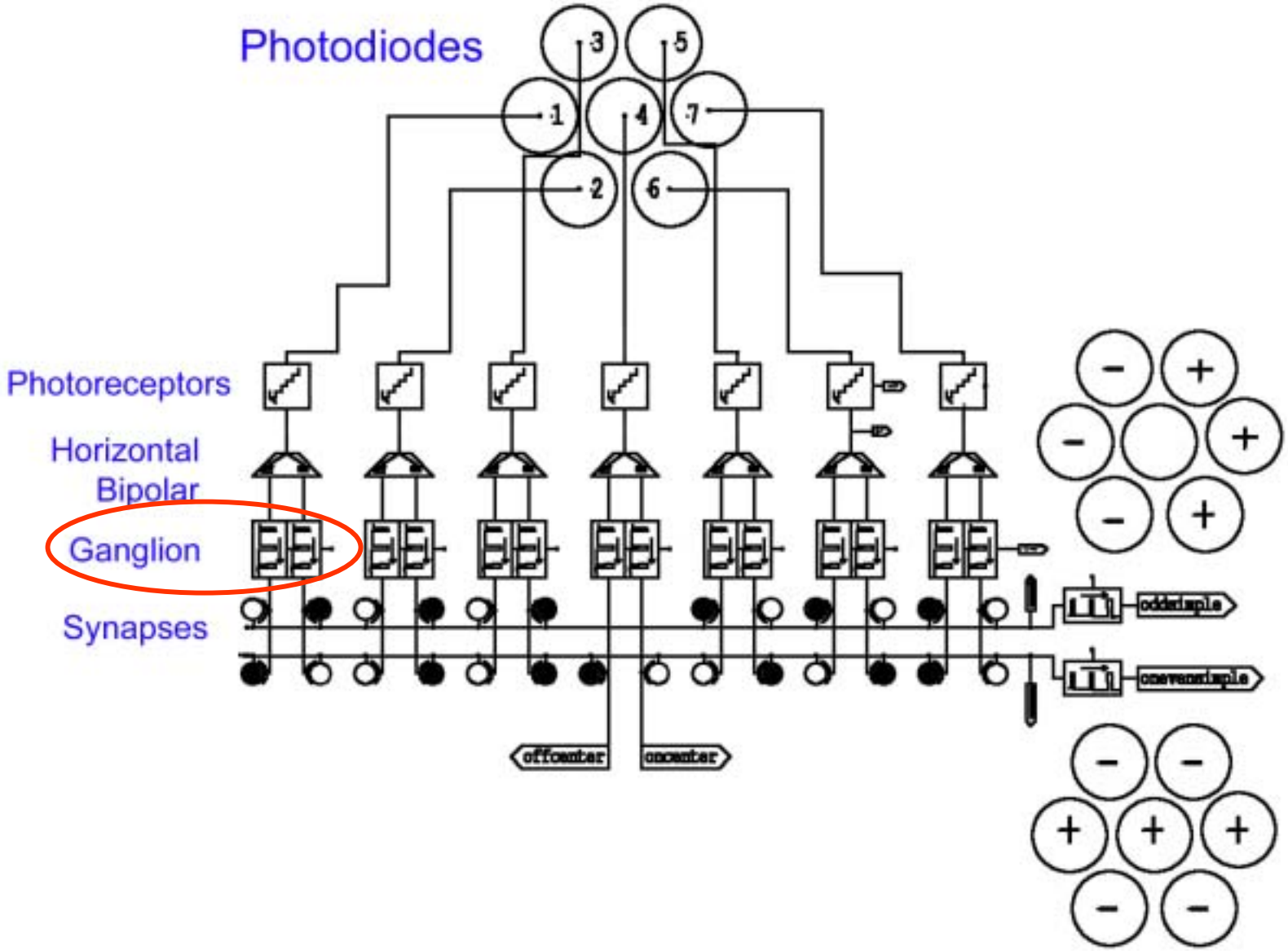
Rectifies into ON and OFF currents





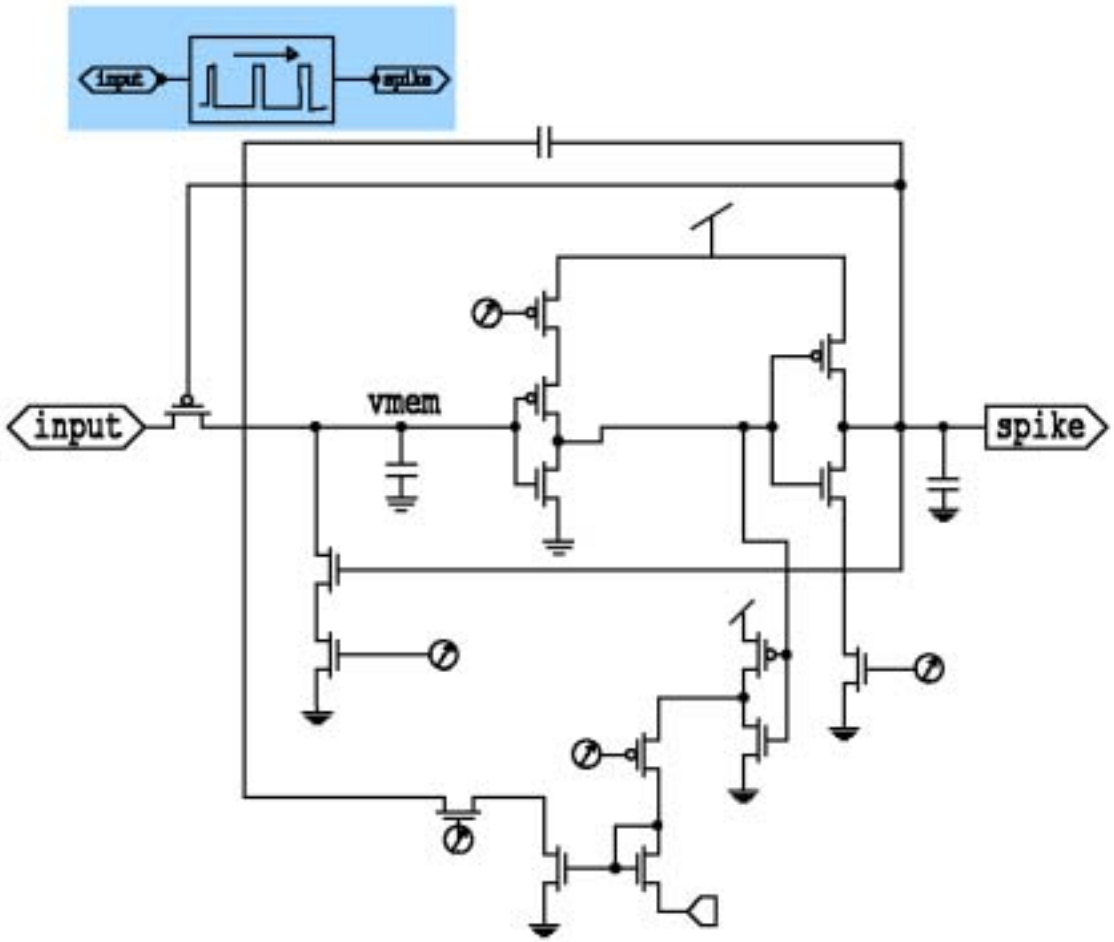
Steals center part of diff pair current

Ganglion cell layer



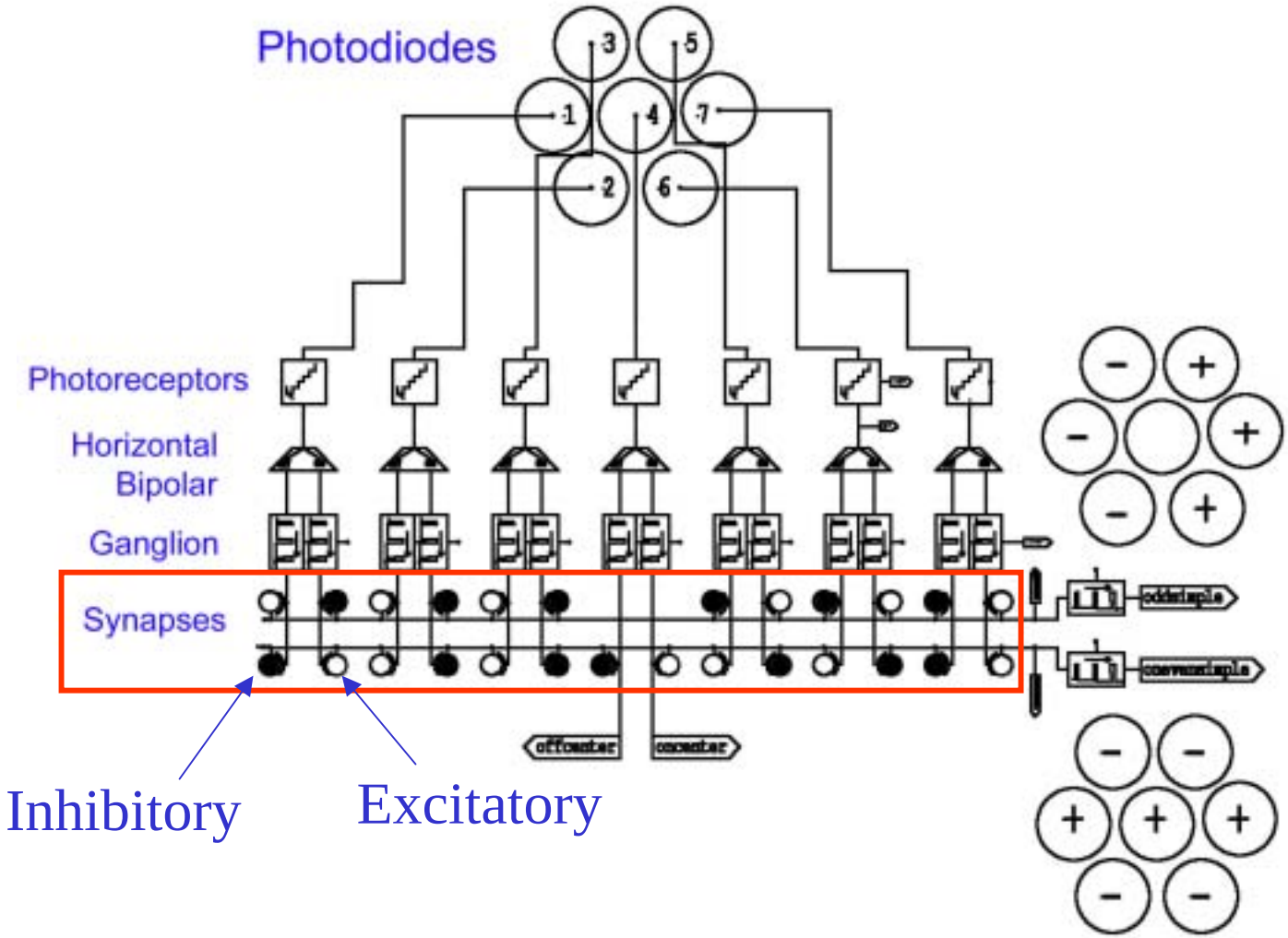
Ganglion/Simple cells have integrate and fire somas with spike adaptation

(Mead/Boahen)



Dendritic Trees of Simple Cells

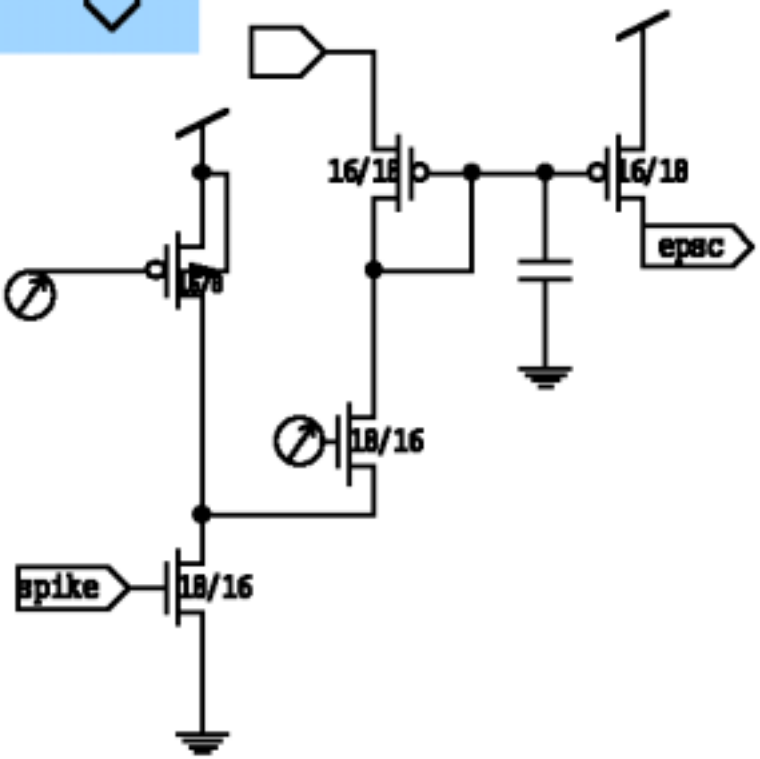
Are arranged to make orientation tuned simple cells with push-pull inputs



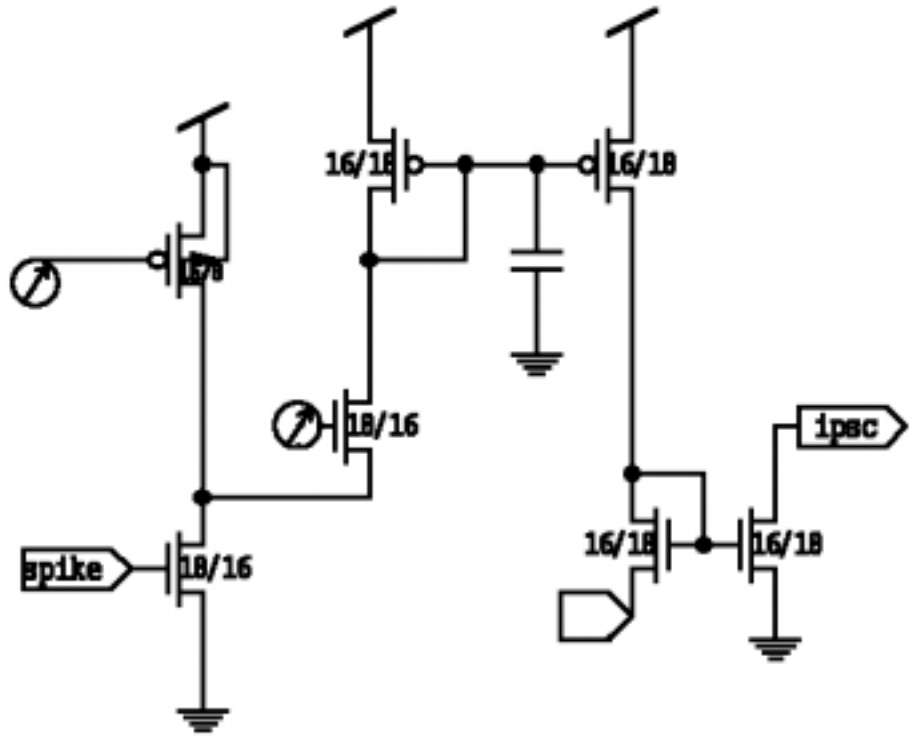
Simple cell synapses

Inject slow pulses of charge with each spike

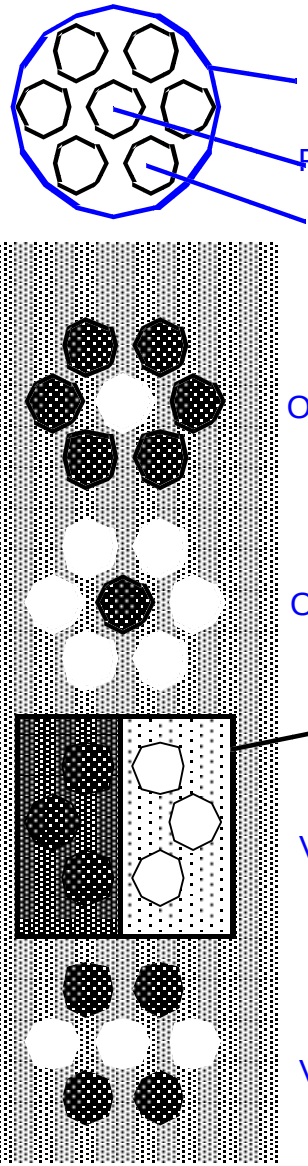
Excitatory



Inhibitory



Receptive fields of outputs



Horizontal cell
(average photoreceptor value)

Photoreceptor (1)

V_{mem}Ganglion cell (2)

Chip output

ON center ganglion (3)

OFF center ganglion (4)

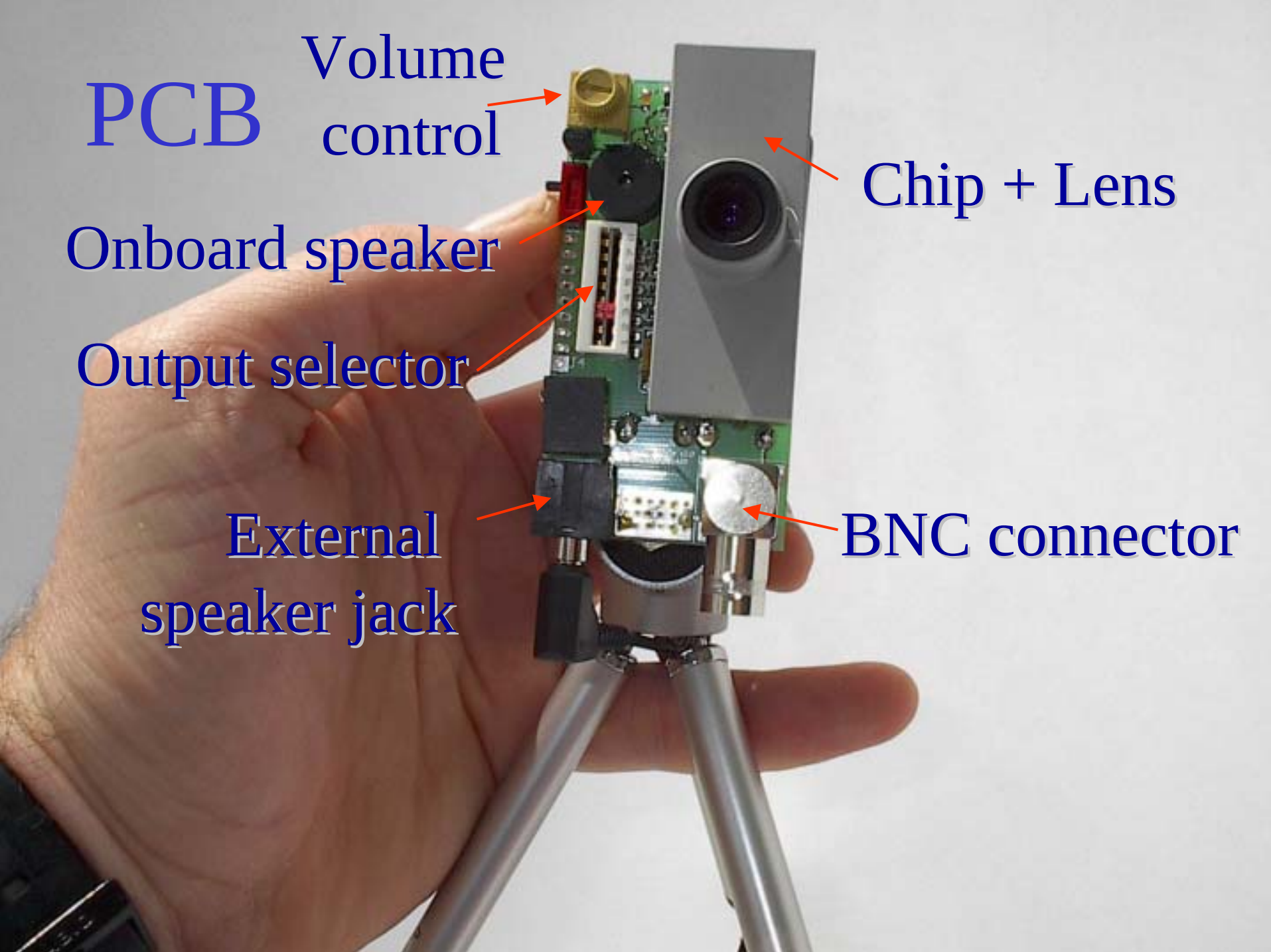
produces maximal response

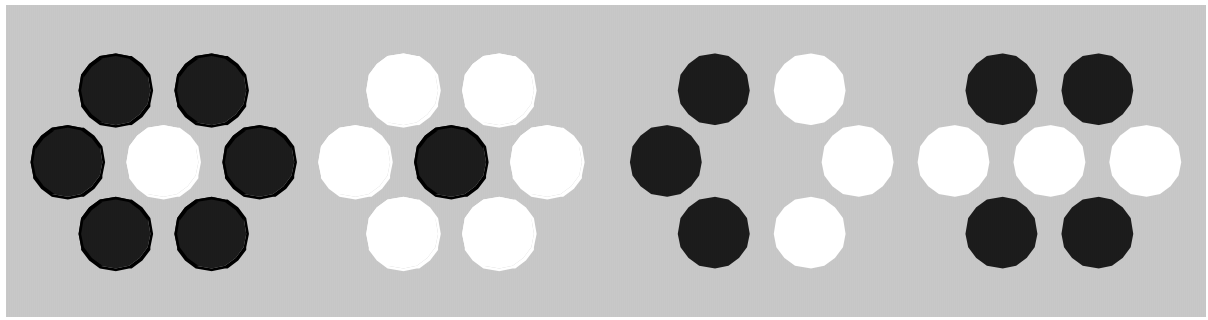
ODD simple (7)

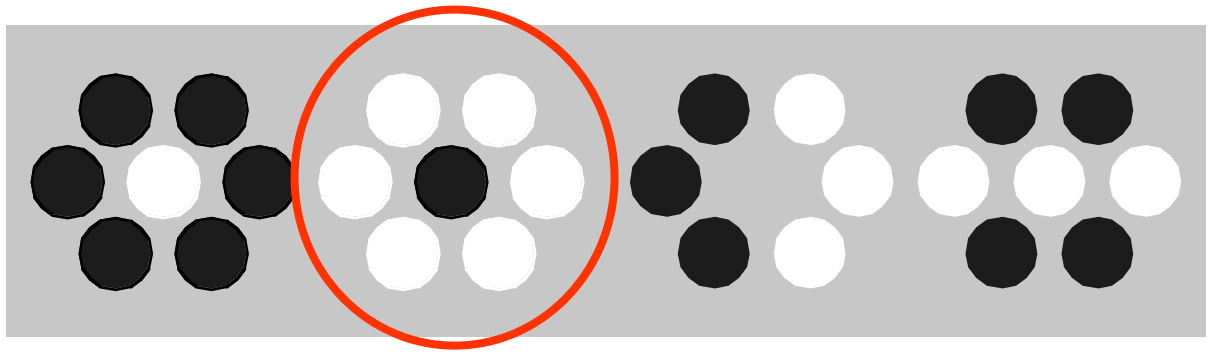
V_{mem}ODD simple (5)

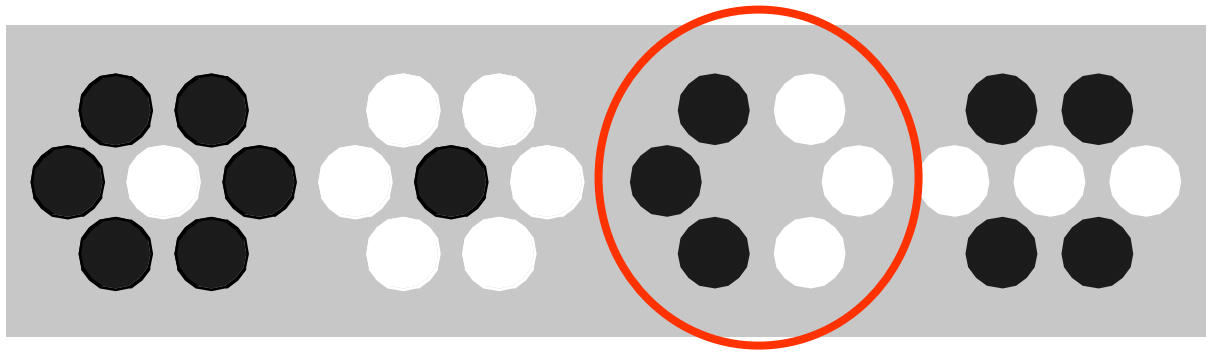
ON EVEN simple (8)

V_{mem}ON EVEN simple (6)

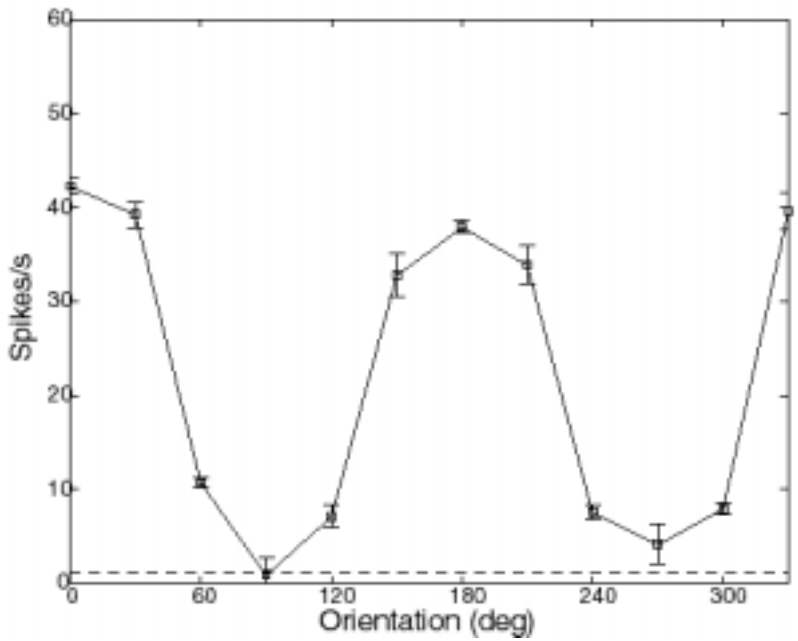

PCB
Volume control
Chip + Lens
Onboard speaker
Output selector
External speaker jack
BNC connector

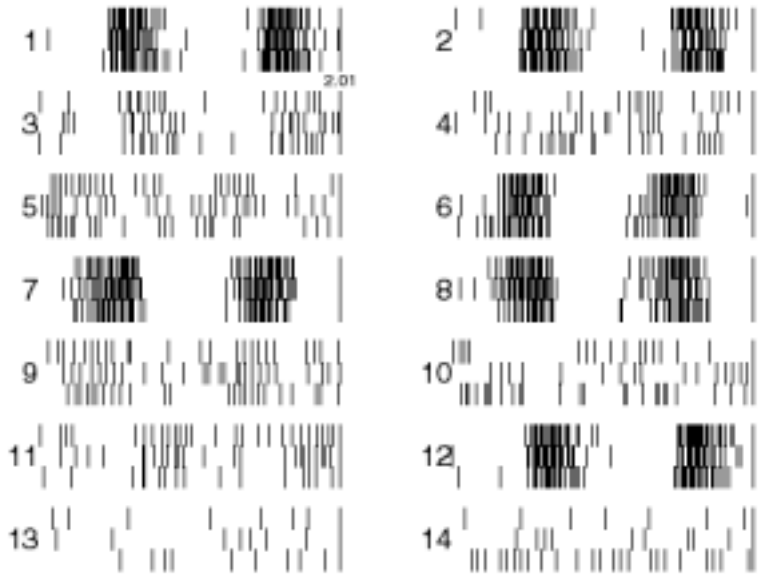






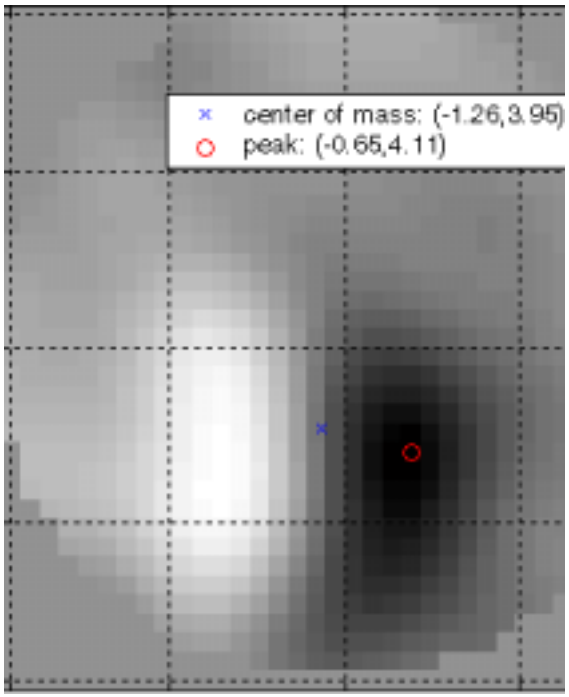
Representative responses to drifting grating with varying orientation

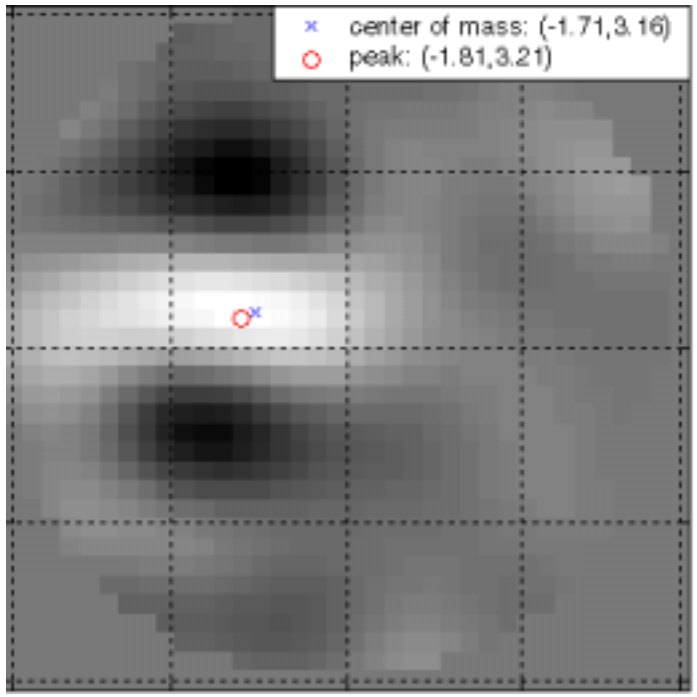




Spatial RFs of simple cells

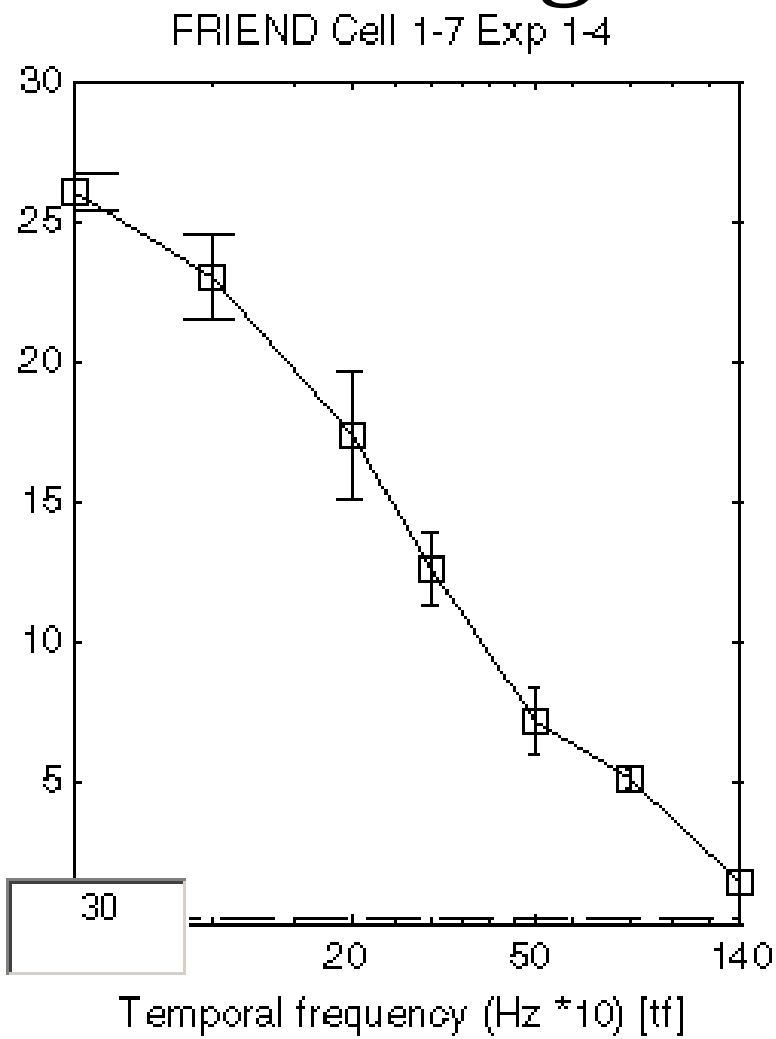
Measured by reverse spike correlation using random orientation stimuli

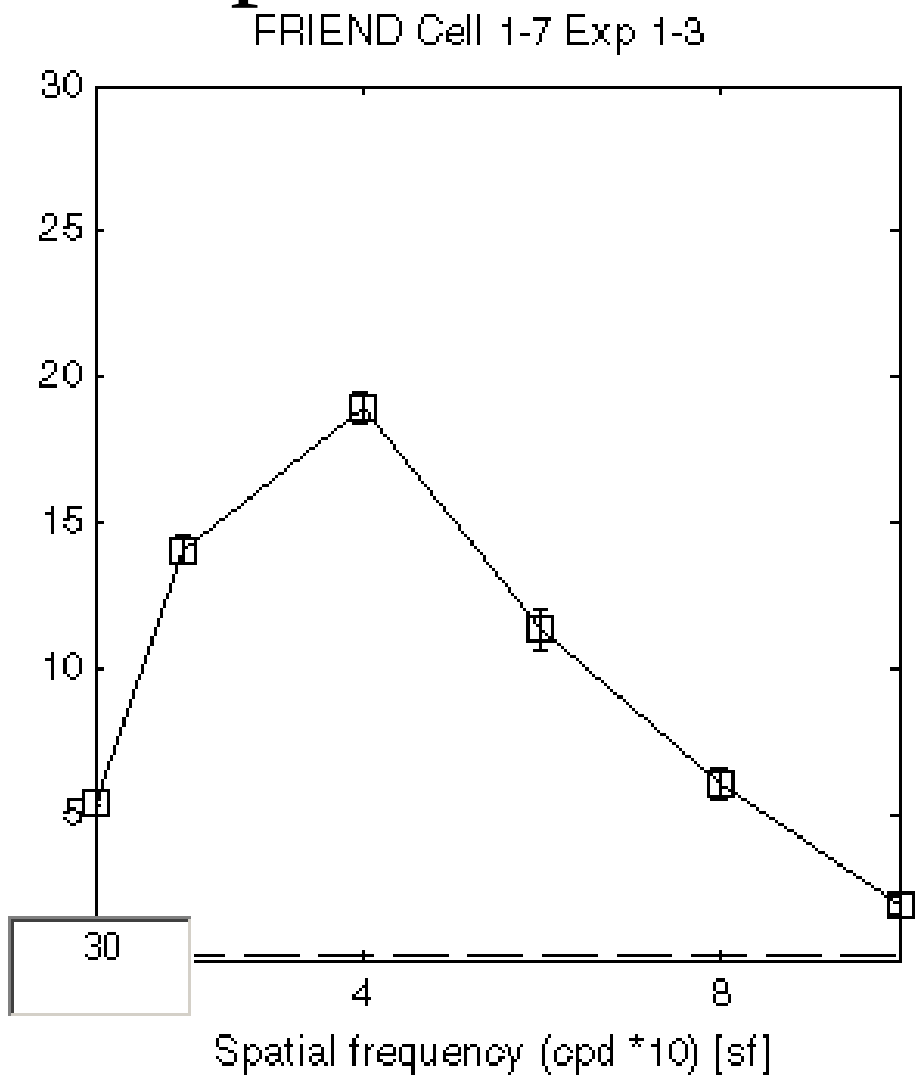




Thanks to Matteo Carrandini

Temporal and spatial frequency tunings of a simple cell





Thanks to Matteo Carrandini

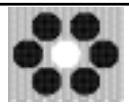
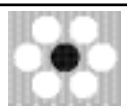
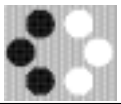
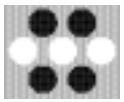
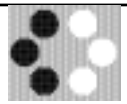
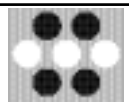
Chip design notes

- Chip simulation: 1s real time takes about 10h on P3 866MHz (TSPICE)
  - Simulations are very stiff numerically
- Cost: Chip ~$220, system ~$360. (dominated by cost of small quantity chip prototypes)

Specifications

Power supply	9V battery 9V DC supply (- on inside)
Power consumption	External speaker: 2.5mA Internal Speaker: 5 to 20mA
Lens	8mm focal length
Neutral density filter	1 decade filter behind lens temporally lowpass filters signal so chip can be used with monitor input
Tripod mount	Standard 1/4” by 20 tripod thread

Quick user guide 1

Cell #	Cell Type	Output type
3	ON ganglion cell 	Spike
4	OFF ganglion cell 	Spike
7	ODD simple cell 	Spike
8	EVEN simple cell 	Spike
5	ODD simple cell 	V_{mem}
6	EVEN simple cell 	V_{mem}
1	Center Photoreceptor	V_{mem}
2	Side Ganglion cell	V_{mem}

Quick user guide 2

- Things to be careful about:
  - Watch out for static electricity (ground yourself before picking up the friendchip). Static can kill the chip!
  - Store the friendchip in an anti-static bag
  - The lens holder is only attached with double stick tape, it can be pulled off.

What we plan

Complex cells

Direction selective cells

Production of ~100 systems for no-profit distribution to labs and teachers

(We have orders for about 30)

Collaborators and Helpers

From INI

Matteo Carandini
Kevan Martin
Tobe Freeman
Jorg Kramer
Giacomo Indiveri

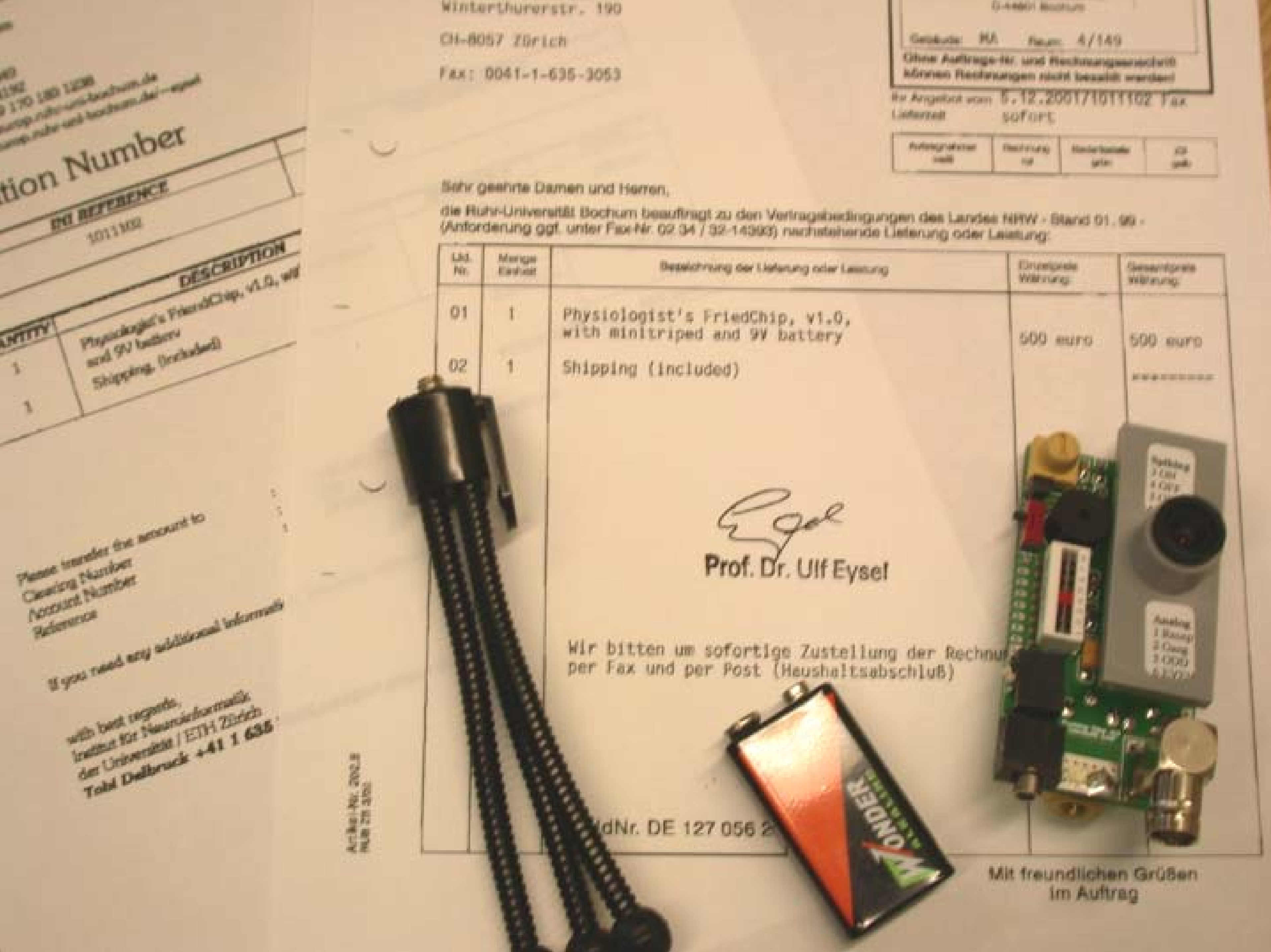
From Telluride Workshop, July 2000

Jeff Dean, Cleveland State, USA
Barbara Claas, Cleveland State, USA
Elana Grassi, Univ. of Maryland, Inst. for Systems Research, USA
Joaquin Sitte, Queensland University of Technology, Australia
Richard Reeve, Stirling University, Scotland
Daljeet Gill, Leicester, UK

Bias circuits

Andre Van Schaik, Univ. of Sydney
Oliver Landolt, Agilent
Bic Schediwy, Synaptics

Supported by the Swiss National Science Foundation


Winterthurerstr. 190
CH-8057 Zürich
Fax: 0041-1-635-3053
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INI REFERENCE
1011102
DESCRIPTION
Physiologist's FriedChip, v1.0, wi
and 9V battery
Shipping (included)
Please transfer the amount to
Clearing Number
Account Number
Reference
If you need any additional informati
with best regards,
Institut für Neuroinformatik
der Universität / ETH Zürich
Tobi Delbruck +41 1 635
Gebäude: MA Raum: 4/149
Ohne Auftrags-Nr. und Rechnungsanschrift können Rechnungen nicht bezahlt werden!
Ihr Angebot vom 5.12.2001/1011102 Fax
Lieferzeit sofort
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die Ruhr-Universität Bochum beauftragt zu den Vertragsbedingungen des Landes NRW - Stand 01.99 - (Anforderung ggf. unter Fax-Nr. 02 34 / 32-14393) nachstehende Lieferung oder Leistung:
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Menge Einheit
Bezeichnung der Lieferung oder Leistung
Einzelpreis Währung
Gesamtpreis Währung
01 1 Physiologist's FriedChip, v1.0, with minitriped and 9V battery 500 euro 500 euro
02 1 Shipping (included)
Prof. Dr. Ulf Eysel
Wir bitten um sofortige Zustellung der Rechnu
per Fax und per Post (Haushaltsabschluß)
dNr. DE 127 056 2
Mit freundlichen Grüßen
im Auftrag
WONDER