Memristive Integrating Sensors

Isha Gupta
I.Gupta@soton.ac.uk
University of Southampton, UK
Date: 15th October, 2015
Overview

- Motivation
- Device Fabrication and Hardware infrastructure
- Memristors as Integrating sensors (MIS)
- Device Characterisation using neural waveforms
- Comparison with Template matching system
- Future Outlook
Motivation

STDP curves for Memristive devices

APPLICATION: Memristors can be used to perform the function of digital thresholded input integral thereby assisting in energy efficient on-node data processing for big neural data.

Device fabrication & Hardware Infrastructure

Stack Structure: Ti/Pt/TiO$_{2-x}$/Pt (5/10/25/10nm)

Memristive Integrating sensor

- Voltage (V)
  - $V_{th+} = +1.45V$
  - $V_a$
  - $V_{th-} = -1.65V$

- Resistance (kΩ)
  - Threshold

Pulse Number

- Resistance (kΩ)
- Time (s)

- Voltage (V)
- Resistance (kΩ)

- Threshold

- Time (s)

- Voltage (V)
- Resistance (kΩ)

- Time (s)

- Voltage (V)
- Resistance (kΩ)

- Time (s)

Neural Recordings: Data Courtesy of Prof. Ralf Zeitler, Max Plank Institute, Germany.

Memristive Integrating sensor

**SCHEMATIC OF MIS**

- **Front end**
- **G**
- **Bias generator**
- **Read circuit**
- **ΔR extract**
- **Threshold**
- **Spikes**

**Software**

1. Offset
2. Hardware

(External CMOS MTA)

**SCHEMATIC OF TEMPLATE MATCHING SYSTEM**

- **Front end**
- **Data aggregation synchronisation**
- **2D kernel convolution**
- **Threshold /peak detection**
- **Spikes**

**Neural Recordings**: Data Courtesy of Prof. Ralf Zeitler, Max Plank Institute, Germany.

**Cell culturing**: Courtesy of Prof. Stefano Vassanelli, University of Padua, Italy.
Signal Conditioning and Spike count estimation in MIS

Spike detection results from MIS and template matching system

- Spiking events are missed by template matching system at 0.85s, 1.05s, 1.1s, 1.35s.
- Spiking events are missed by MIS at 0.6s, 1.22s.

Schematic of Template Matching system

Future Outlook: Memristive Integrating Sensor Array

On-chip processing which can be integrated with CMOS process

Scaling of the concept of MIS to multi-channel array level

$t_1 = 1.63s$
$t_2 = 3.27s$
$t_3 = 5.16s$

Output from MIS Devices

Off-chip Memristors
Read-out/ Data processing

Output from Template Matching system
Summary

- Inherent properties of solid-state TiO$_x$ memristors can be used to distinguish spiking activity from noise.
- Qualitative similarity to template matching benchmark.
- Relatively low sampling rate traded-off for timing resolution.
- Can be useful for applications in Neuroprosthetics.
Thank you.
Any Questions?

Acknowledgements:
Dr. Themis Prodramakis, University of Southampton, UK
Dr. Alexantrou Serb, University of Southampton, UK
Dr. Ali Khiat, University of Southampton, UK
Prof. Stefano Vassanelli, University of Padova, Italy
Prof. Ralf Zeitler, Max Planck Institute, Germany