RUB

A Sensory Driven Adaptive Central Pattern Generator

Jonas Röhrig, Bakr Al Beattie, Sebastian Jenderny, Karlheinz Ochs

Chair of
Digital
Communication Systems

Faculty of
Electrical Engineering and
Information Technology

Contents

Contents

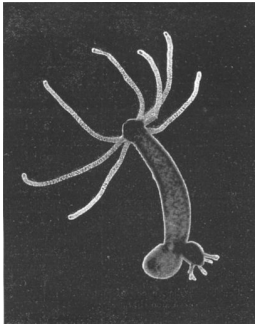
Central Pattern Generator (CPG)

What is a CPG

- Clusters of neurons that autonomously generate rhythmic muscle contractions
- Environment may influence oscillation shape and frequency

Why take an interest?

- Fundamental neural circuit
- Model organism Hydra exhibits light modulated rhythmic body contractions
- Involved in chewing, breathing, locomotion, ...
- Relevant for robotics, bio-inspired circuits, ...



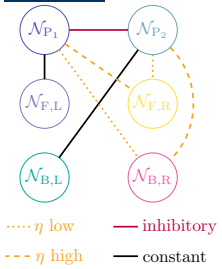
[2]

The goal is to electrically model a CPG where frequency and synchronization patterns are sensory-dependent.

Contents

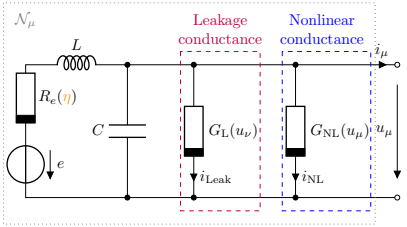
Setup

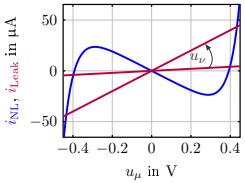
Topology



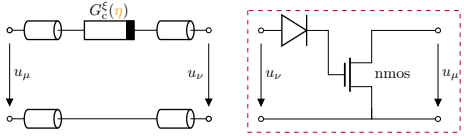
Subcircuits

- Neuron: Leaky FitzHugh-Nagumo oscillator





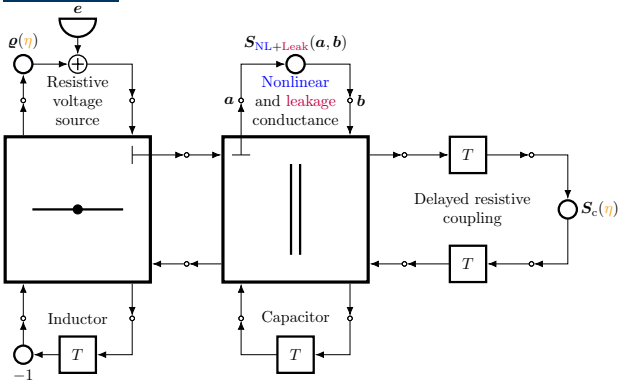
- Axon and synapse: Light sensitive conductor in series with transmission line



Contents

Wave Digital Model

WD Model



Derivation of WD model

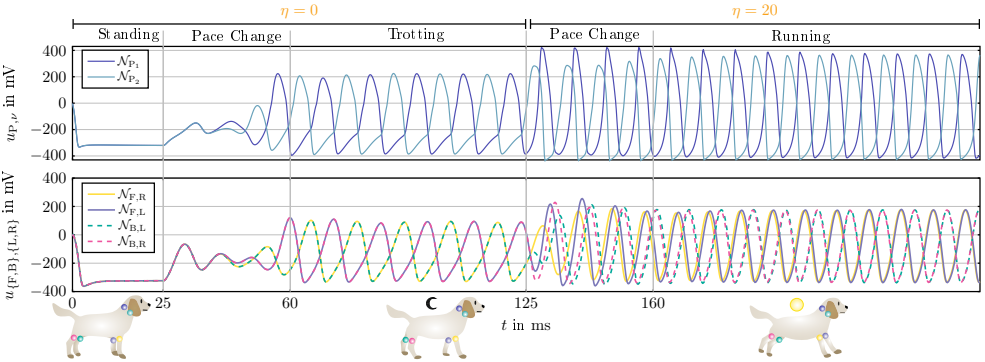
- Port-wise decomposition
- Discretization with the trapezoidal rule
- Variable transformation from electrical quantities (u, i) to wave quantities (a, b)
- Port-wise reassembly of the components

Enables efficient emulation.

Contents

Emulation

Results



Synchronization patterns and frequency change.

Contents

Conclusion

- CPGs are fundamental neural circuits
- In our technical implementation
  - Neurons are implemented with FNOs
  - Light-sensitive resistors in FNOs enable frequency change
  - A leakage conductance enables inhibitory coupling
  - Couplings with light-sensitive conductors enable synchronization pattern change
- The circuit is verified via a wave digital model
- Synchronization pattern and frequency variation can be observed
- Further reading: [1]

Sources

[1] Bakr Al Beattie et al. “Light-Controlled Switching of Gait Patterns in a Central Pattern Generator: Circuit Design and Emulation.” In: *2023 30th IEEE International Conference on Electronics, Circuits and Systems (ICECS)*. IEEE. 2023, pp. 1–4.

[2] Harry Hamilton Johnston, John Lubbock, and Walter Hutchinson. *Marvels of the universe: a popular work on the marvels of the heavens, the earth, plant life, animal life, the mighty deep*. 1913.