Neuromorphic VLSI-Based Bat Echolocation Using Interaural Level Differences

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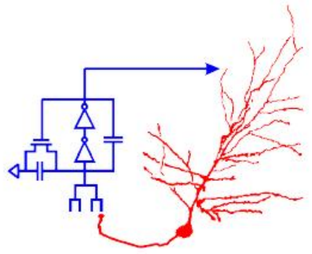


Introduction

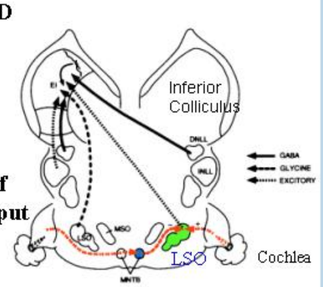
- This is part of an active project in the *C*omputational *S*ensorimotor *S*ystems *L*ab (CSSL) that aims to model, design, and build a small, rapidly moving, echolocating, physical model of the big brown bat (***Eptesicus fuscus***).
- The bat's small head size and its use of high frequency sounds make the interaural level differences (ILDs) the primary cue for azimuthal echolocation. This project is to model bat's ILD pathway and to build a VLSI-based hardware system that mimics bat's ILD azimuthal echolocation behavior.

Motivation

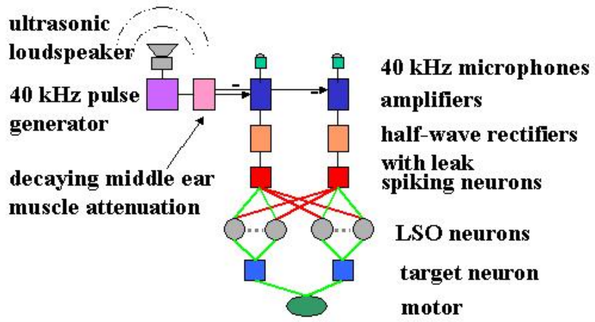
- **Bats are unique in their auditory systems:**
  - The bat's echolocation system operates on a very short time scale (a few msec) and provides a good case for studying the role of timing and spike population coding in neural computation.
  - Bats are very good examples for studying ILDs.
- **Hardware modeling of bat's ILD pathway**
  - Hardware modeling often provides different perspectives from software simulation.
  - By building hardware systems that must operate under similar constraints as biological systems, we can gain some insight into the tradeoffs and optimizations that evolution has used.

LSO and IE Cell

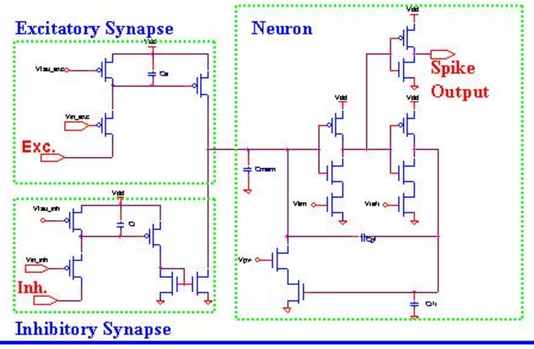
- **Shown on the right is the bat's ILD pathway from cochlea to inferior colliculus (IC).**
- **The first ILD processing center is called the *Lateral Superior Olive (LSO).***
- **The LSO is primarily composed of neurons that receive excitatory input from the ipsilateral ear and inhibitory input from the contralateral ear, called IE cells.**



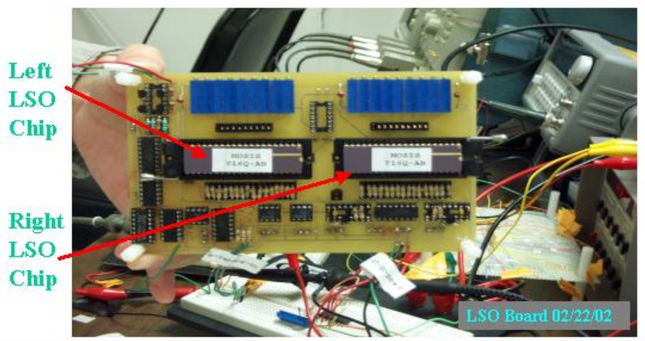
Block Diagram of Hardware System



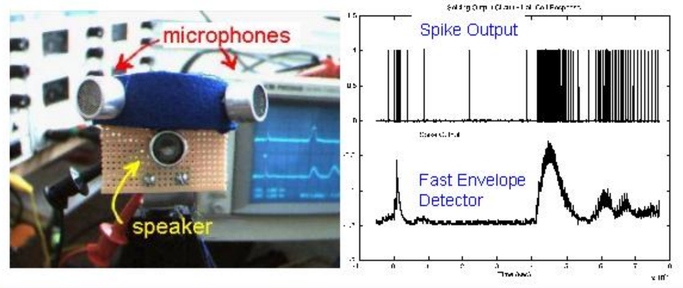
The LSO IE Cell Circuit



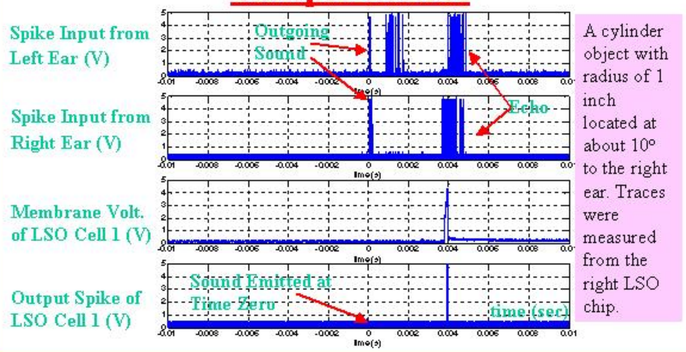
The LSO Board



The Front End



Sample Traces



A cylinder object with radius of 1 inch located at about 10° to the right ear. Traces were measured from the right LSO chip.

Summary and Future Work

- **We have presented**
  - a narrow band azimuthal ultrasound echolocation system
  - a spike-based hardware model of bat's LSO
- **In future, we are going to extend it to**
  - a wide band front end that emits FM signals
  - a multiple frequency channel system by including cochlea chips
  - a spike-based hardware model of bat's ILD pathway including LSO, DNLL, and IC.
  - a multi-chip VLSI system using address-event representation protocol for interchip communication.