MORPHING THE BARN OWL’S SOUND LOCALIZATION SYSTEM IN SILICON

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Project Description:

Neuromorphing is an approach to implement neural algorithms into silicon. Neuromorphic designs usually operate within the subthreshold region of a transistor. They perform computations in both analog and digital domains and are capable of real-time operations. With the fact that none of the existing computers can process information as efficient and robust as the brain, we engineers believe that we can learn something from the ‘well-engineered’ brain.

The barn owl can hunt in complete darkness. It can localize and predict the trajectory of the prey by listening to the rustles made by the prey. Since its neural mechanism for sound localization in both cellular and network level is relatively well studied, I would like to implement the barn owl’s sound localization system using a neuromorphing approach.

Neurobiology preliminary – How the barn owl localizes sound?

Since the interaural time difference (ITD), i.e. the difference of the sound arrival time between the two ears, changes systematically along the azimuthal axis, the location of sound can be computed by finding out the ITD. In fact this is what is done in the barn owl auditory system.

After the filtering in cochlear, incoming sound stimuli are bandpassed and the output spikes (impulses) generated by the auditory nerves are phase-locked. The ITD can then be computed by cross-correlation. With a delay line structure (Figure 1), an array of neurons will be sensitive to different ITD. This is an example of a change in timing code (Phase-Locking) to place code (The array of neurons). This strategy is common in neural computation.

![Model circuit for sound localization](From Konishi 1993)

*Figure 1: Model circuit for sound localization (From Konishi 1993)*
**System Block Diagram:**

Inspired by neural algorithm described above, I have designed a sound localization sensor with similar morphology, as shown in the diagram below.

![System Block Diagram](image)

**Circuit Schematics:**

There are three main circuits in my design: a delay element (Figure 2a) which delays an incoming spikes to an arbitrary time, a coincidence detector (Figure 2b) which output current represents the degree of coincidence of the spikes, and a 1D resistive network which computes the centroid of the array of output currents from the coincidence detection. The 1D resistive network (Figure 2c) makes the sensor center-biased.

![Circuit Schematics](image)
Results and Discussion:

The results that show the functionality of the circuits are shown in Figure 3. We see from Figure 3a that the delay time can be varied by the bias voltage and the achievable delay is about 1us to 160us. From Figure 3b and 3c, we see that there is a big difference in the time response and the charge output of the coincidence detector to different ITD respectively. Thus the sound location can be detected.