Operational Amplifier Axons

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November 16, 2024

Abstract

In the spirit of FitzHugh and Nagumo [1], in this note, the authors develop and characterize an op-amp circuit, suggesting that its output can be sampled to obtain an action potential profile. They further suggest the next few steps that lead to a full realization of 3D ephaptic coupling in electronic form, distinct from the pde model usually used to simulate 3D axon bundles in computer software like MATLAB.

Electronic neurons are often studied for example in [2] in the context of analog VLSI circuits. Similar structures find applications in cochlear implants for example [3]. The present note is the first to our knowledge to aim solely at ephaptically coupled axons in tracts.

In [4] the authors developed a 3D equation governing action potential propagation in axon tracts under the coupling condition. The root of that work is [5] where simple current-voltage relations in a chain of resistors allow the derivation of the ephaptic equation.

In the present note, the authors consider a chain of three op-amps, each in a noninverting amplifier configuration [6] followed by RC low pass filters. The gains of the three op-amps are adjusted so that the envelope follows a low-high-lower profile which is characteristic of the action potential shape.

The opamp circuit is illustrated in Figure 1 and the output is shown in Figure 2. With sampling at equispaced time points, the action potential waveform is recoverable from the output envelope. The next steps would be to place two or three such daisy chains next to one another and couple them as per the analysis in [7, 8]. The final goal would be to simulate 3D axon tracts in electronic form and compare the output with MATLAB pde based simulations.

References

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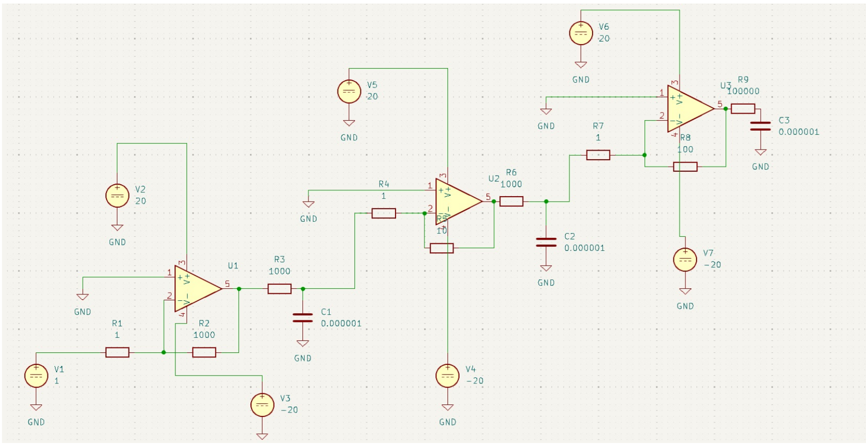

Figure 1: Op-amp Circuitry.

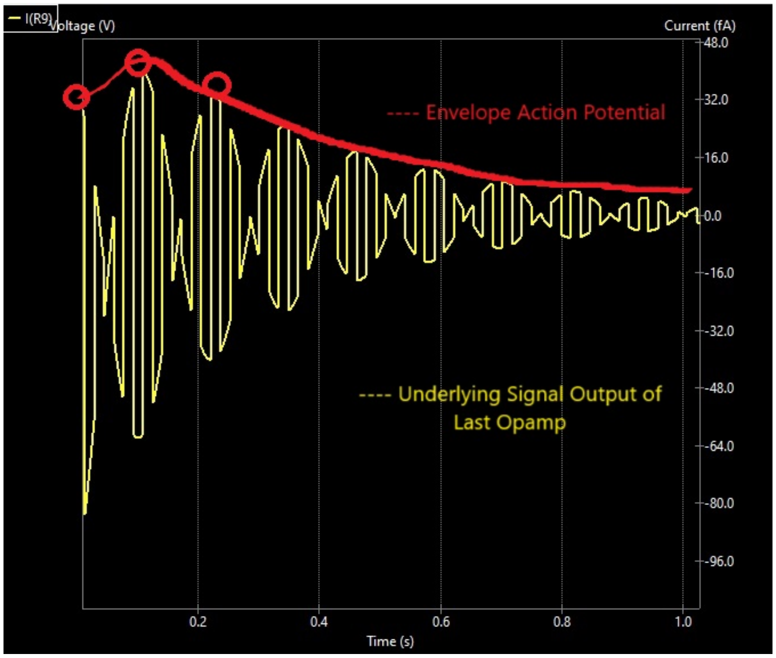

Figure 2: Output of op-amp circuitry.

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