

Neuroprothetik Exercise 6

Electric Stimulation

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1 Calculate the Potential Field

The goal of this exercise is calculating the potential at a distance r from a current point-source, that can be calculated by:

$$\Phi = \frac{\rho}{4\pi} * \frac{I}{r} \quad (1)$$

1.1 Potential Field

Using the following parameters, plot the potential field for a $50 \mu m$ by $50 \mu m$ slice in a distance of $10 \mu m$ from the point source. With parameters: $medium = 300 \Omega cm$, $I = 1 mA$. The results can be seen in 1.

1.2 Activation Function

Calculate and plot a) the external potential (2) b) the electric field (3) c) the activation (4) function along a $50 \mu m$ piece of axon positioned $10 \mu m$ from a current point source. Plot the three graphs for a electrode current of $1 mA$ and for $-1 mA$

2 Create a Neuron Model

The exercised aimed to enhance the neuron model implemented in exercise 6, to now consider an the influence of an external potential. Given parameters were used: $\rho_{axon} = 0.01 k\Omega cm$, $r_{axon} = 1.5 * 10^{-4} cm$, $l_{comp} = 0.5 * 10^{-4} cm$,

2.1 Stimulate the Axon

The following stimulation sequences were created and run with your axon positioned as in section. Run the simulation for about 30 ms and position your pulse at $t=5 ms$

1. Stimulation by a mono-phasic current pulse, phase duration = 1 ms, current = -0.25 mA (5)
2. Stimulation by a mono-phasic current pulse, phase duration = 1 ms, current = -1 mA (6)
3. Stimulation by a bi-phasic current pulse (negative phase first), phase duration = 1 ms, amplitude = 0.5 mA (7)
4. Stimulation by a bi-phasic current pulse (negative phase first), phase duration = 1 ms, amplitude = 2 mA (8)
5. Stimulation by a mono-phasic current pulse, phase duration = 1 ms, current = 0.25 mA (9)
6. Stimulation by a mono-phasic current pulse, phase duration = 1 ms, current = 5 mA (10)

2.2 Interpretation of the result

1. Mono-phasic current pulse of -0.25 mA caused an external field outside of the multi-compartment model. The neurons between 40 and 60 got excited, but the change in their potentials did not elicit a spike. The shape (amount of compartments that were influenced by the external field (2) can be explained by the distance from the spike on 50 element on the axon. We can also notice dark blue spots, indicating decreasing voltage.
2. Mono-phasic current pulse of -1mA also caused a change of compartments potential and then elicit spikes on the close neurons, that later on propagated through the model. The potential went up to around 100 mV, indicating spiking(6). Two spike trains can be explained by the shape of the activation function (4).
3. Stimulation with bi-phasic action potential of amplitude -0.5mA did not cause the spike. Impulse of the potential has to integrate to the specific size to cause excitation of the neurons. Due to bi-phasic type of the stimulation, the shape caused by the V_e is different.
4. Bi-phasic current of 2mA cause same behavior as in the experiment 2.
5. Application of small mono-phasic positive pulse of 0.25 mA caused slight hyperpolarization (decreased potential) of the compartments influenced by it (opposite to (5)).
6. Monophonic pulse of 5mA caused voltage drop around compartments 40 to 60 (up to -25mV). As in other experiments, around the main point of stimulation the opposite voltage filed appeared (dark blue parts in (5)). In this case went positive and above the threshold. Electric field caused activation of further compartments and action potentials propagating through the corresponding compartments.

3 Plots

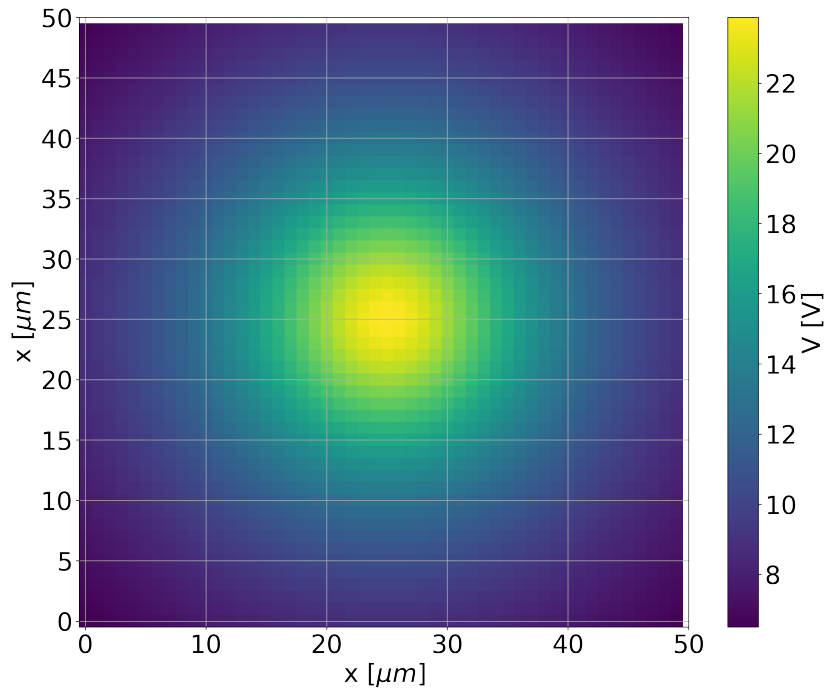


Figure 1: The potential field for a $50\mu\text{m}$ by $50\mu\text{m}$ slice in a distance of $10\mu\text{m}$ from the point source.

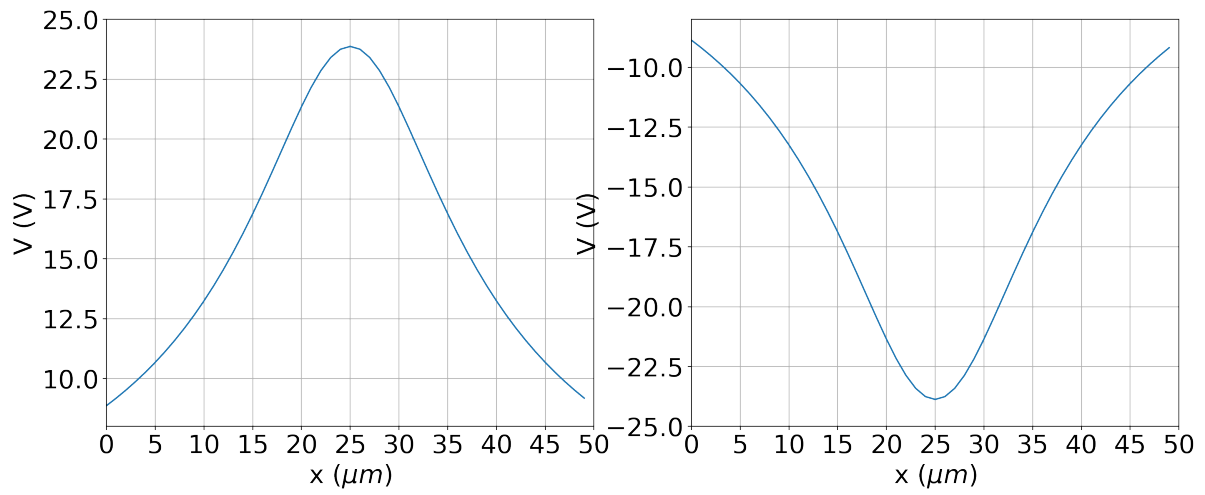


Figure 2: The external potential along a $50\mu\text{m}$ piece of axon positioned $10\mu\text{m}$ from a current point source.

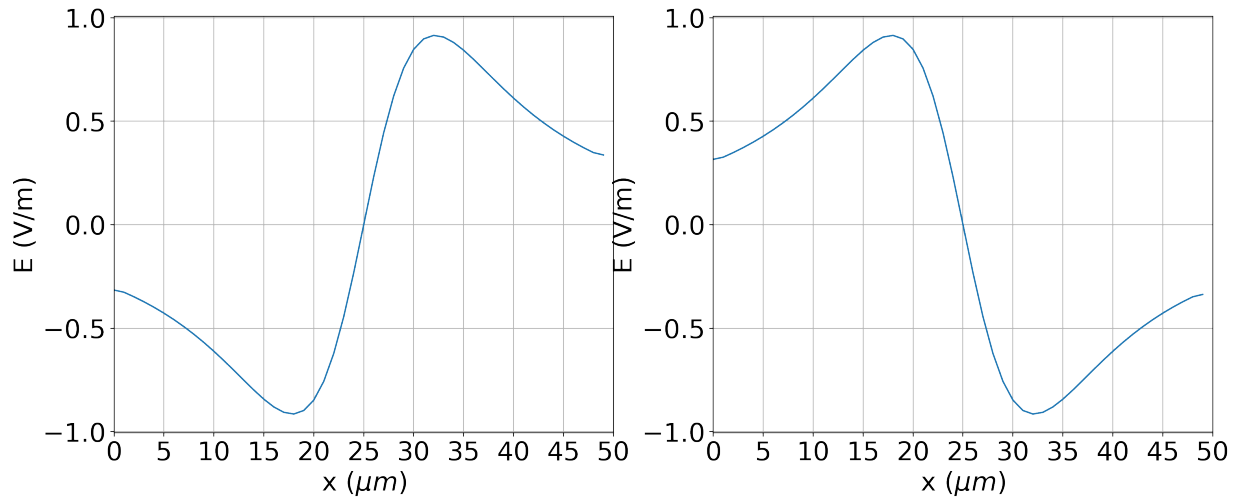


Figure 3: The electric field along a 50 μm piece of axon positioned 10 μm from a current point source.

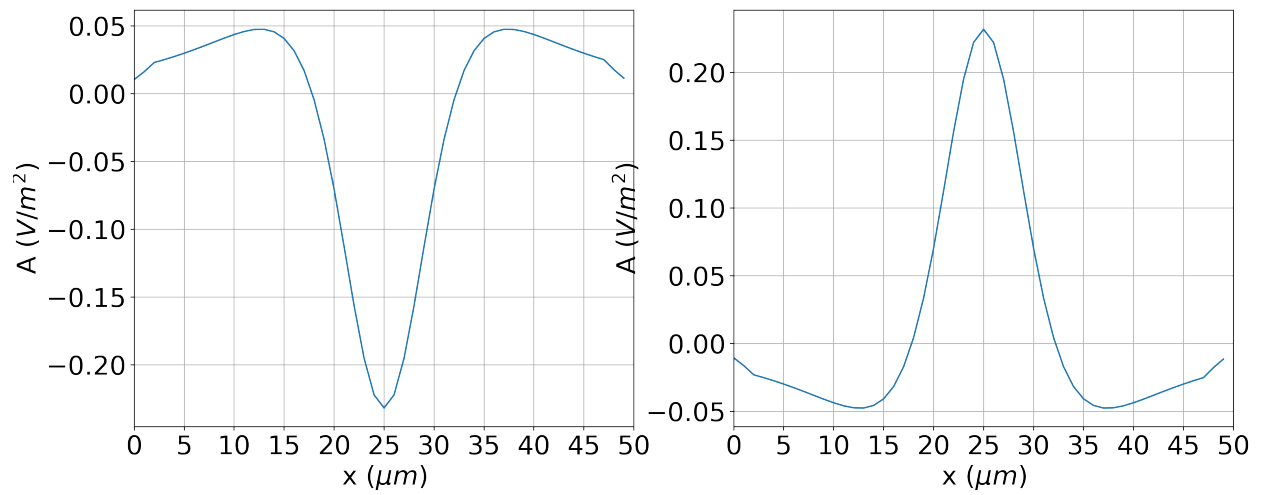


Figure 4: The activation function along a 50 μm piece of axon positioned 10 μm from a current point source.

3.1 Exercise 2

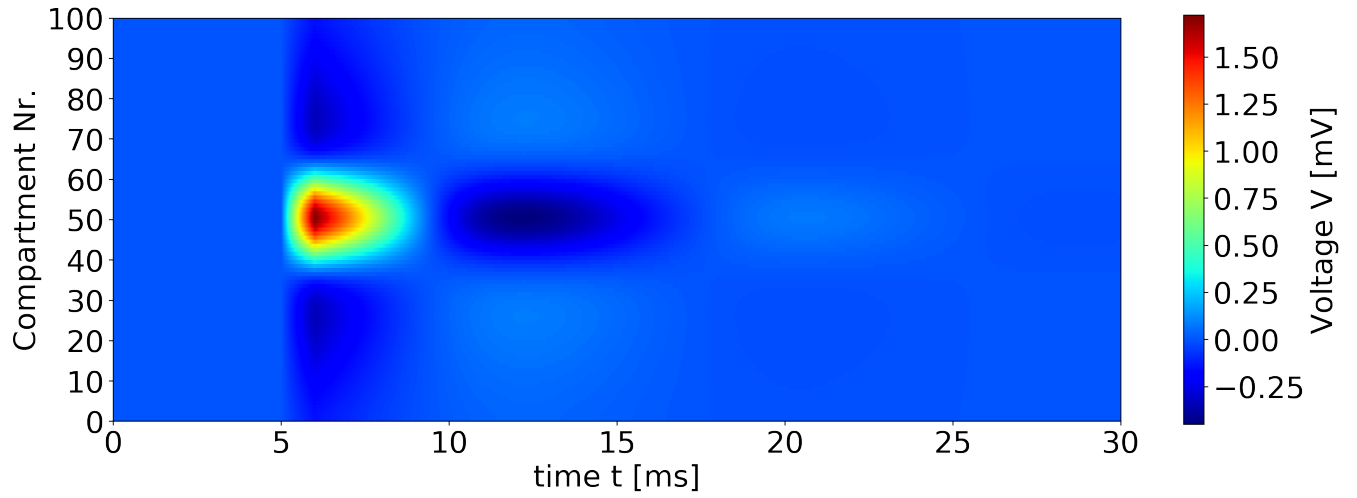


Figure 5: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: mono-phasic pulse with -0.25 mA.

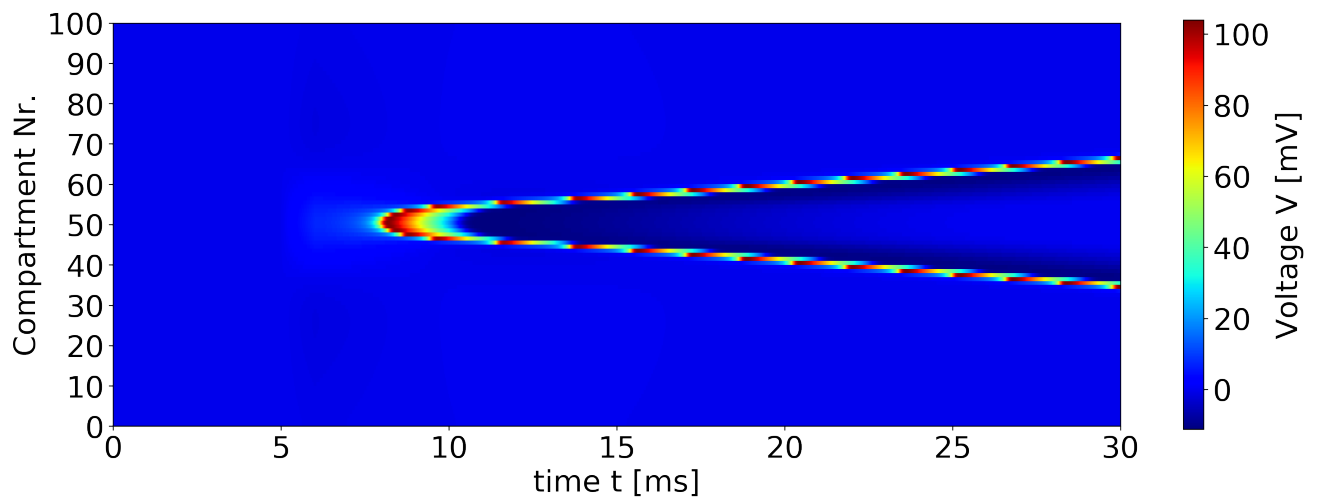


Figure 6: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: mono-phasic pulse with -1 mA.

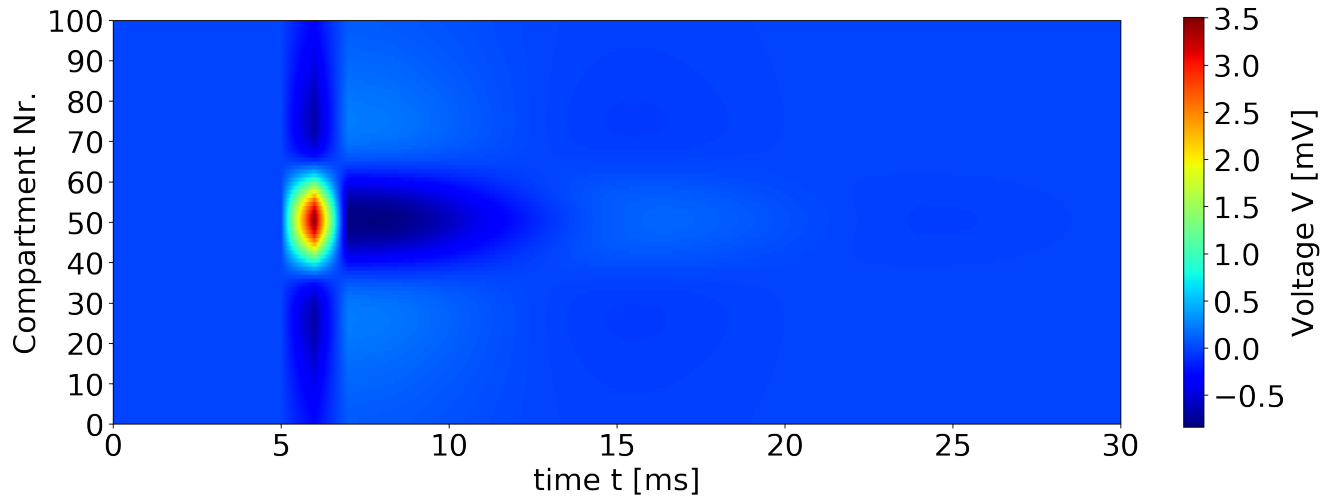


Figure 7: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: bi-phasic pulse with 0.5 mA.

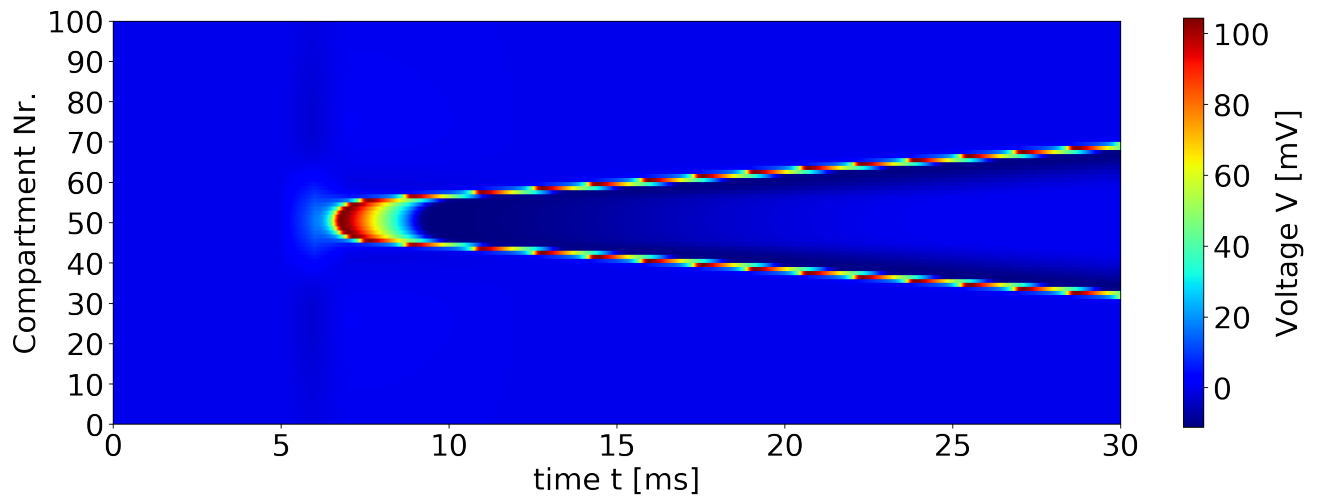


Figure 8: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: bi-phasic pulse with 2 mA.

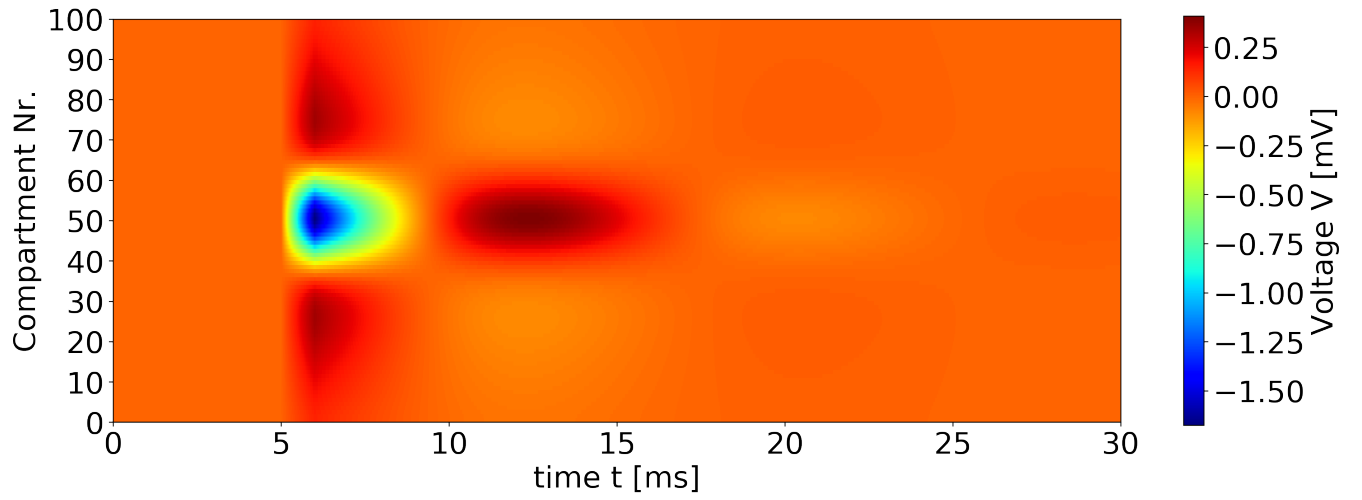


Figure 9: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: mono-phasic pulse with 0.25 mA.

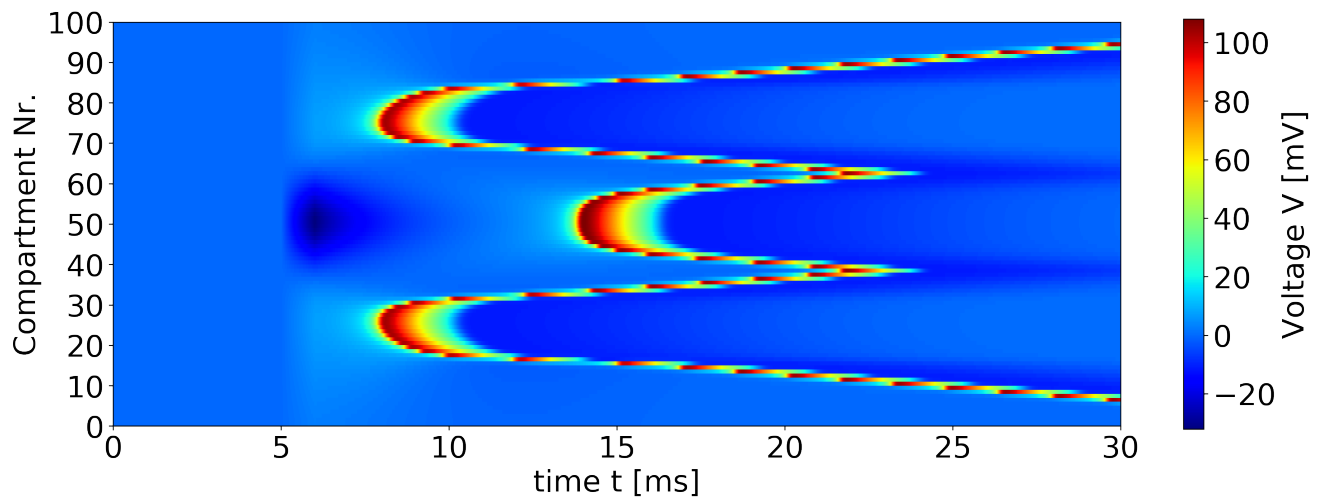


Figure 10: Propagation of the action potential when stimulated at $t = 5$ ms with a phase duration of 1 ms. Additionally parameter: mono-phasic pulse with 5 mA.