Week 1 – part 2: The Passive Membrane

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

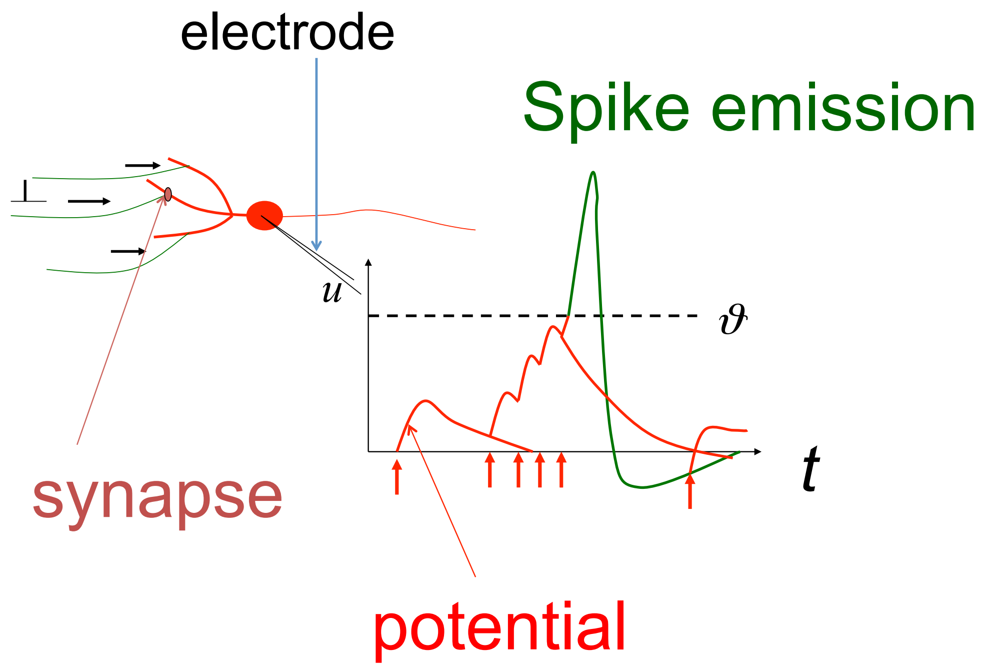
Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 1 – neurons and mathematics: a first simple neuron model

Wulfram Gerstner

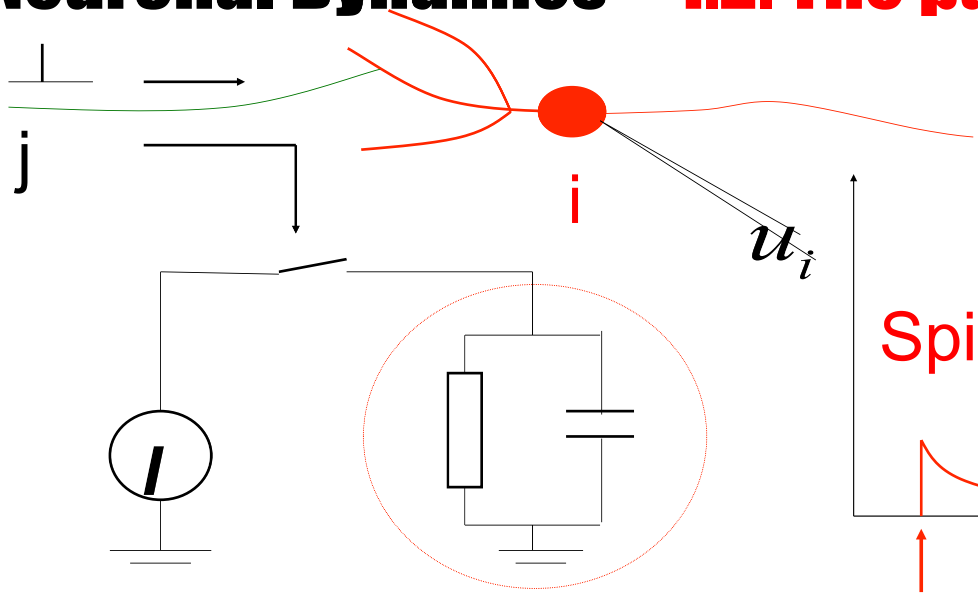
EPFL, Lausanne, Switzerland

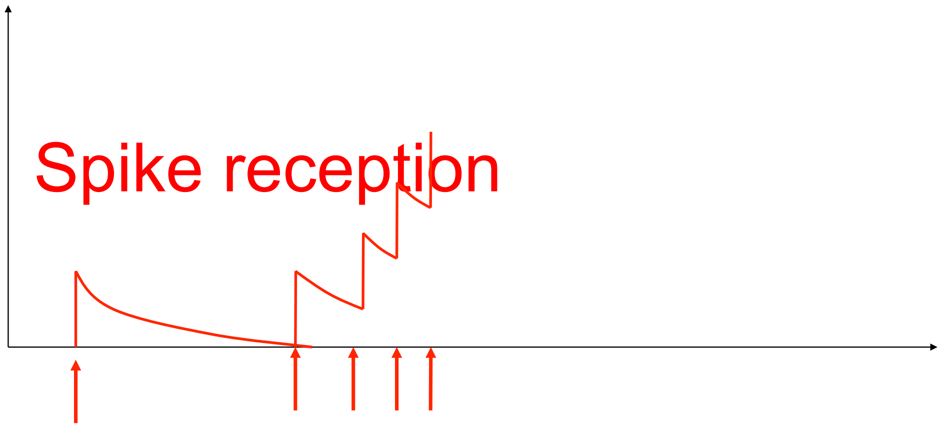
Neuronal Dynamics – 1.2. The passive membrane



Integrate-and-fire model

Neuronal Dynamics – 1.2. The passive membrane

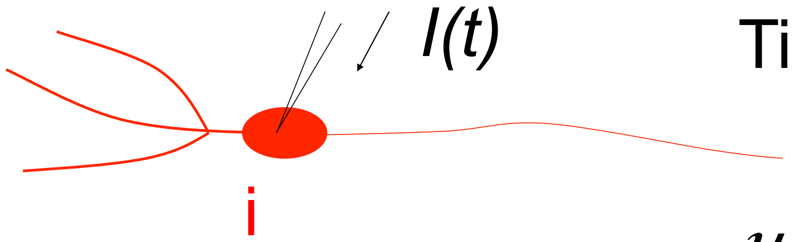




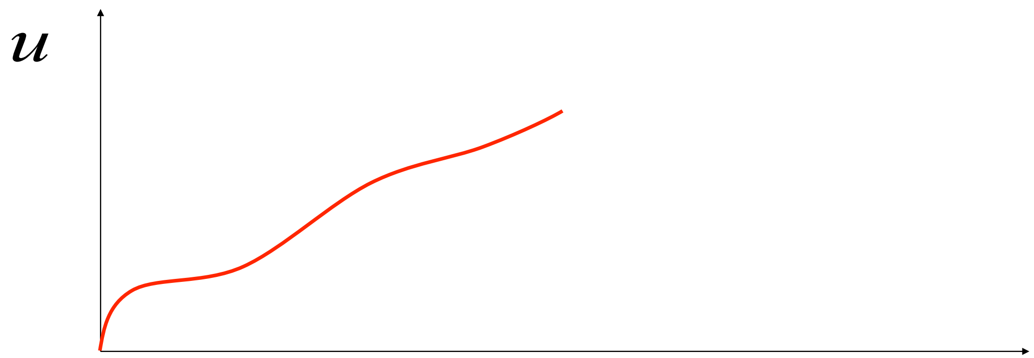
Subthreshold regime

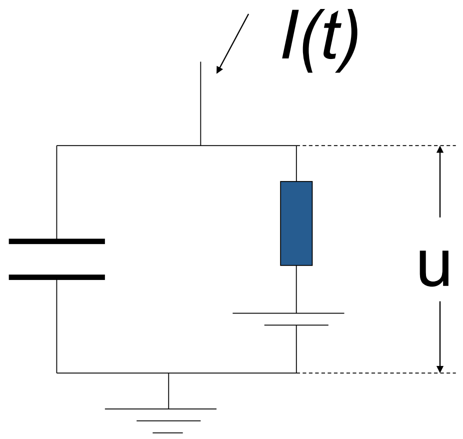
- linear
- passive membrane
- RC circuit

Neuronal Dynamics – 1.2. The passive membrane



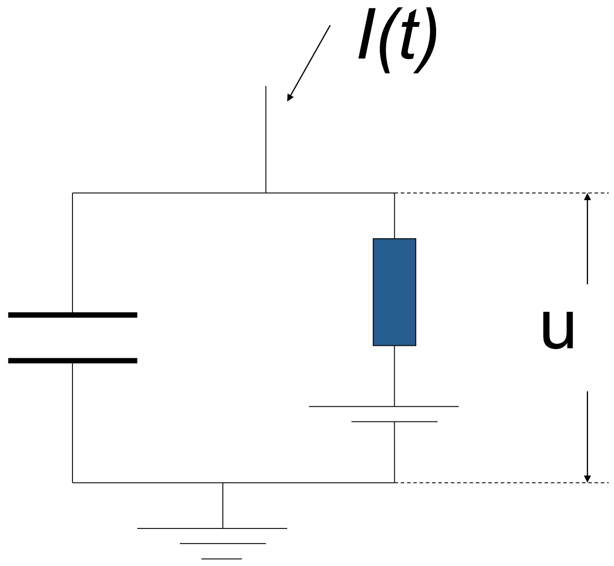
Time-dependent input



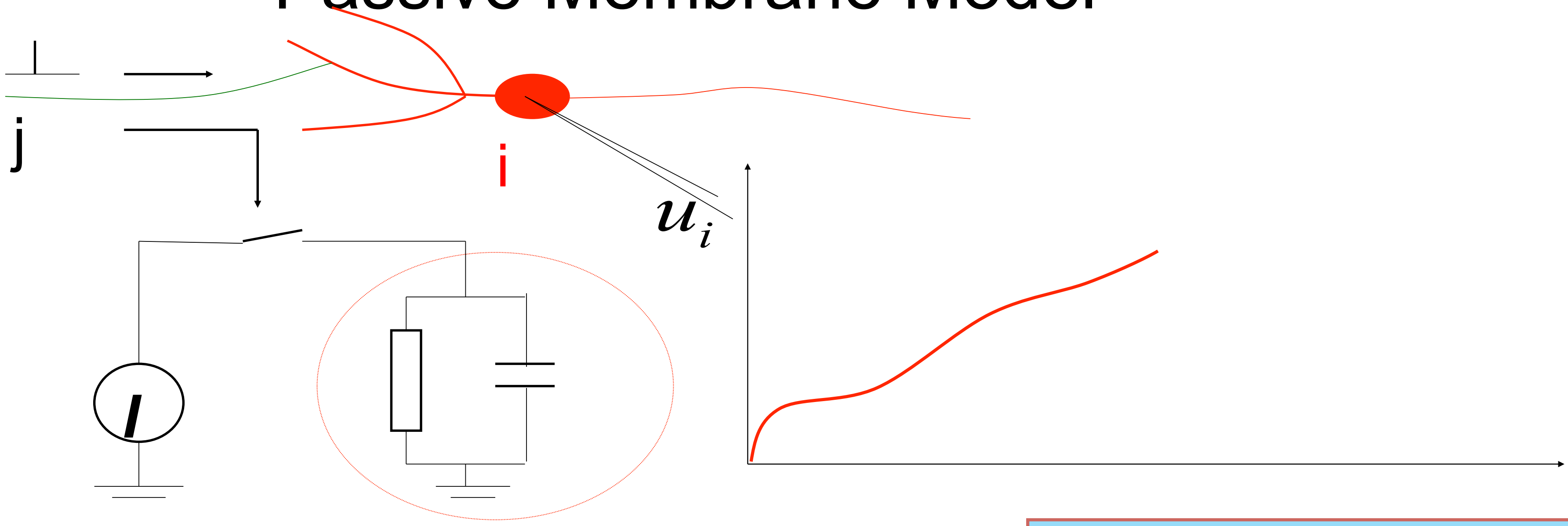


Math development:
Derive equation

Passive Membrane Model



Passive Membrane Model



$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

$$\tau \cdot \frac{d}{dt} V = -V + RI(t); \quad V = (u - u_{rest})$$

Math Development: Voltage rescaling

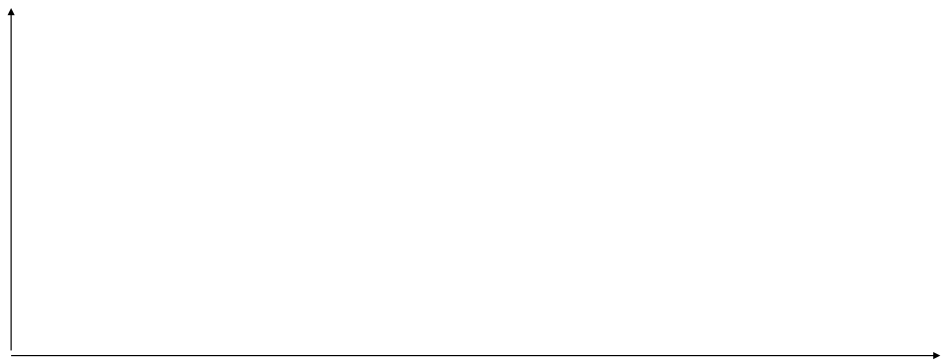
Passive Membrane Model

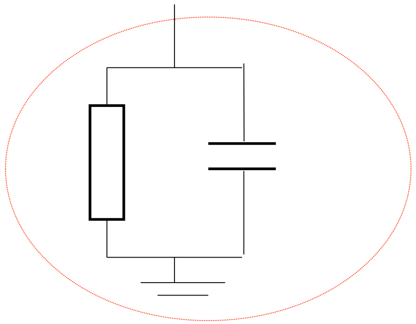
$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

$$\tau \cdot \frac{d}{dt} V = -V + RI(t); \qquad V = (u - u_{rest})$$

Passive Membrane Model/Linear differential equation

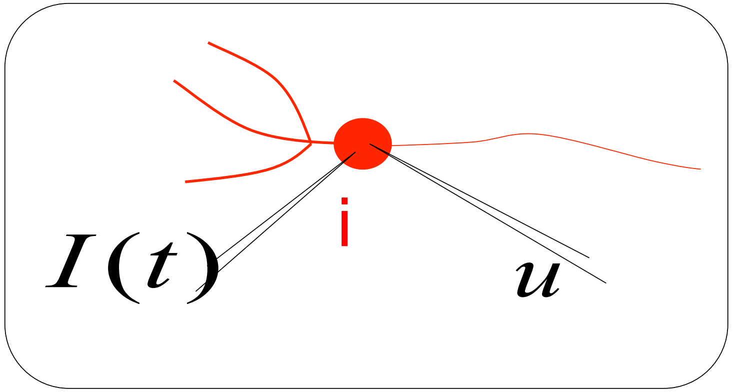
$$\tau \cdot \frac{d}{dt} V = -V + RI(t);$$

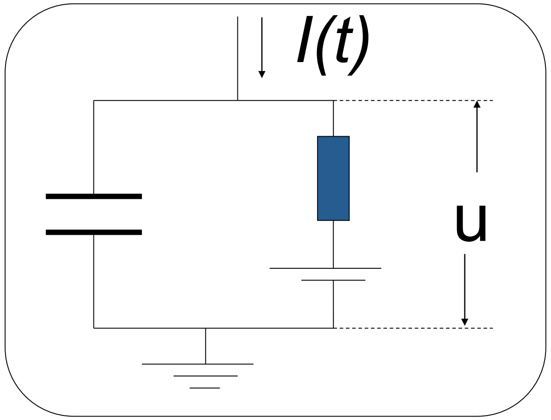




Free solution:
exponential decay

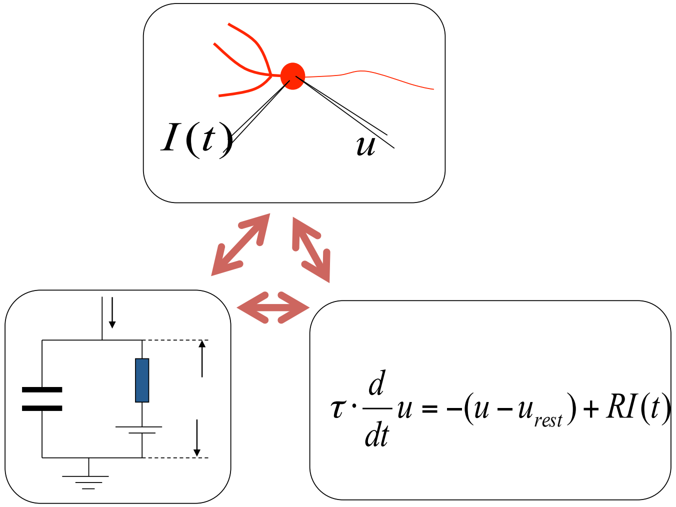
Triangle: neuron – electricity - math





$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

Pulse input – charge – delta-function

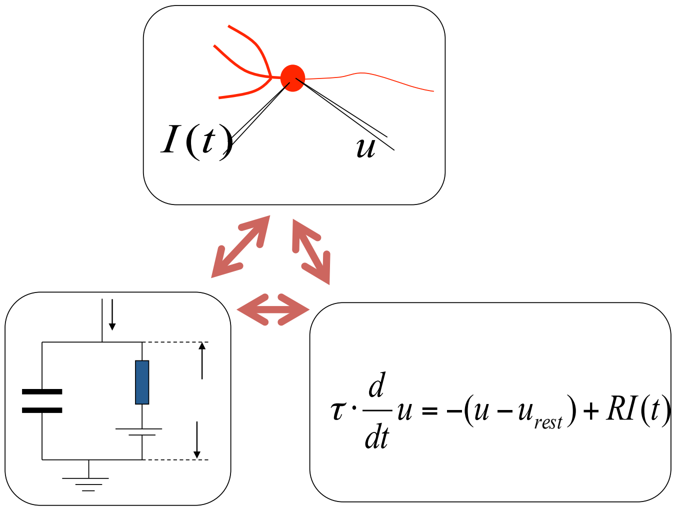


$$I(t) = q \cdot \delta(t - t_0)$$

Pulse current input

Dirac delta-function

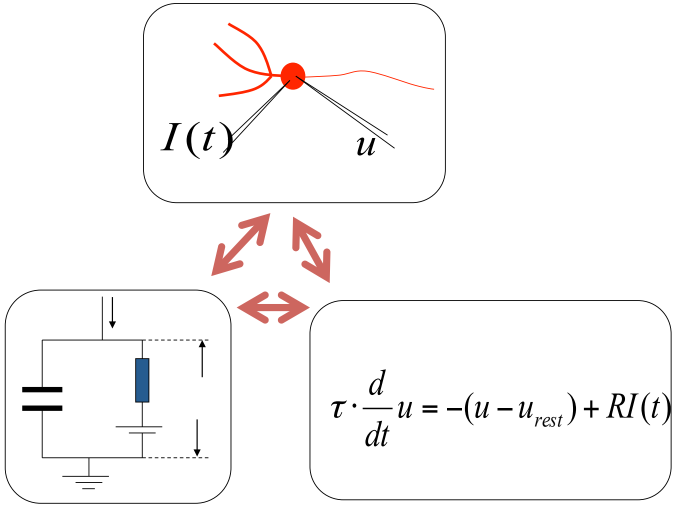
$$I(t) = q \cdot \delta(t - t_0)$$



$$1 = \int_{t_0 - a}^{t_0 + a} \delta(t - t_0)\, dt$$

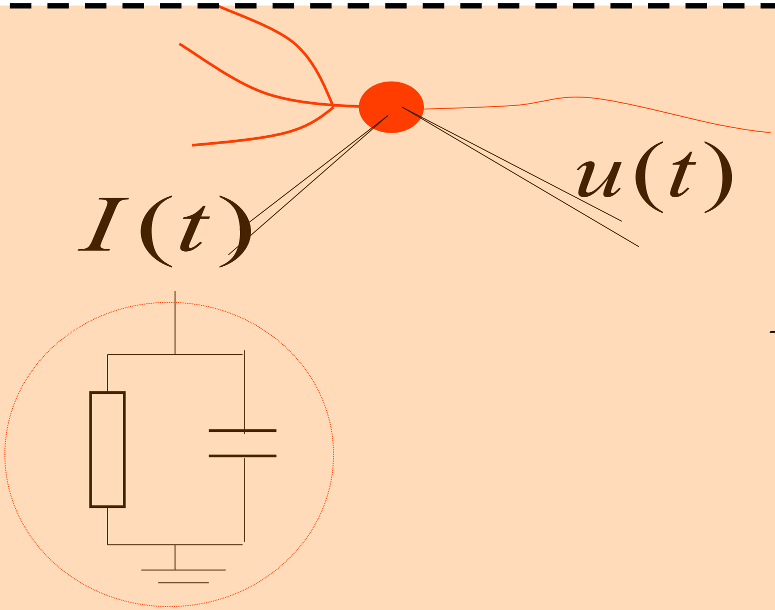
$$f(t_0) = \int_{t_0 - a}^{t_0 + a} f(t)\, \delta(t - t_0)\, dt$$

Passive membrane, linear differential equation



Spend 10-15 minutes on Homework 1.1 now!
If you have difficulties, watch lecture 1.2detour.

Neuronal Dynamics – Exercises 1.2 = Homework 1.1



$I_1(t)$ Step current input:

$I_2(t)$ Pulse current input:

$I_3(t)$ arbitrary current input:

$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

$$\tau \cdot \frac{d}{dt} V = -V + RI(t); \quad V = (u - u_{rest})$$

Calculate the voltage,
for the
3 input currents