Week 4 – part : Type I and Type II Neuron Models

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 4 – Reducing detail:
Two-dimensional neuron models

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EPFL, Lausanne, Switzerland

√4.1 **From Hodgkin-Huxley to 2D**

√4.2 **Phase Plane Analysis**

√4.3 **Analysis of a 2D Neuron Model**

4.4 **Type I and II Neuron Models**
- where is the firing threshold?
- separation of time scales

4.5. **Nonlinear Integrate-and-fire**
- from two to one dimension

Week 4 – part 5: Nonlinear Integrate-and-Fire Model

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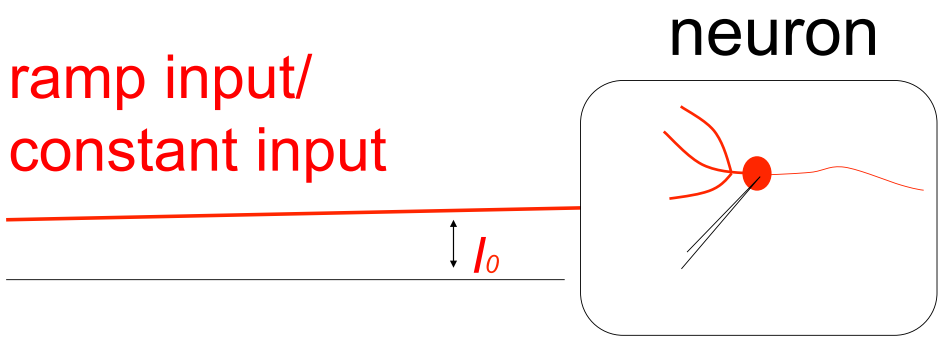
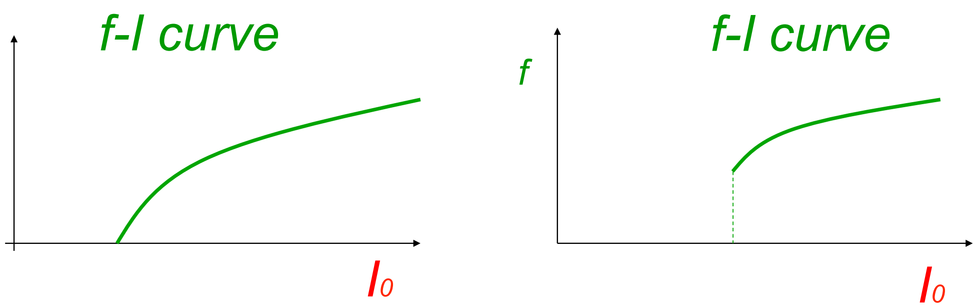
Neuronal Dynamics – 4.4. Type I and II Neuron Models



Type I and type II models



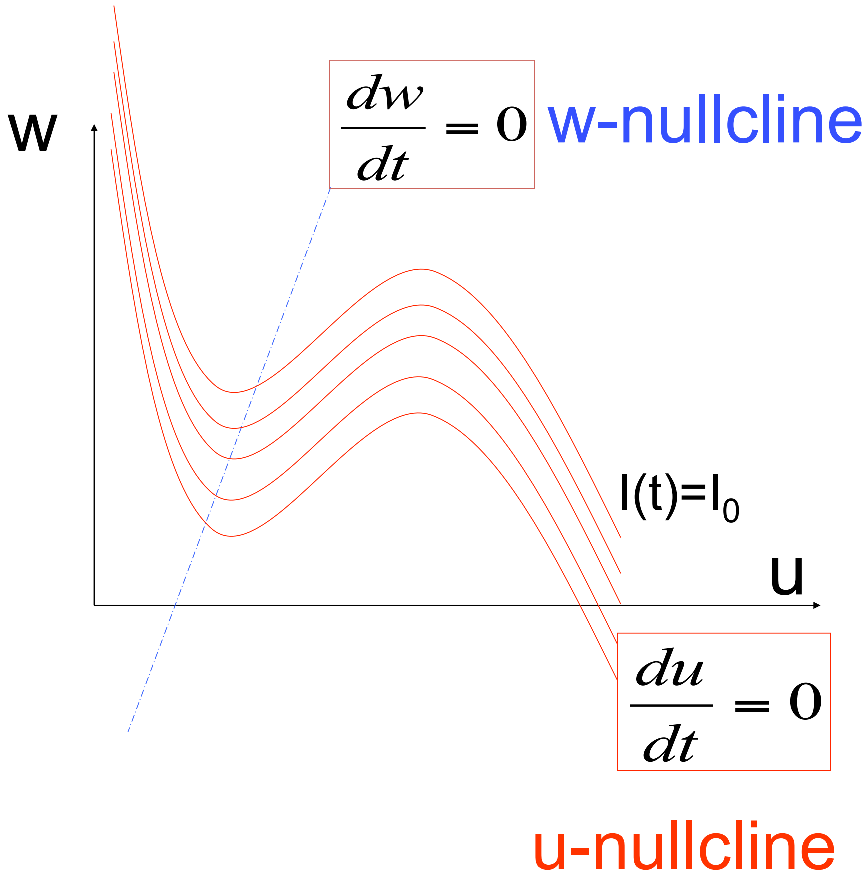
2 dimensional Neuron Models

stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

apply constant stimulus I_0



FitzHugh Nagumo Model – limit cycle

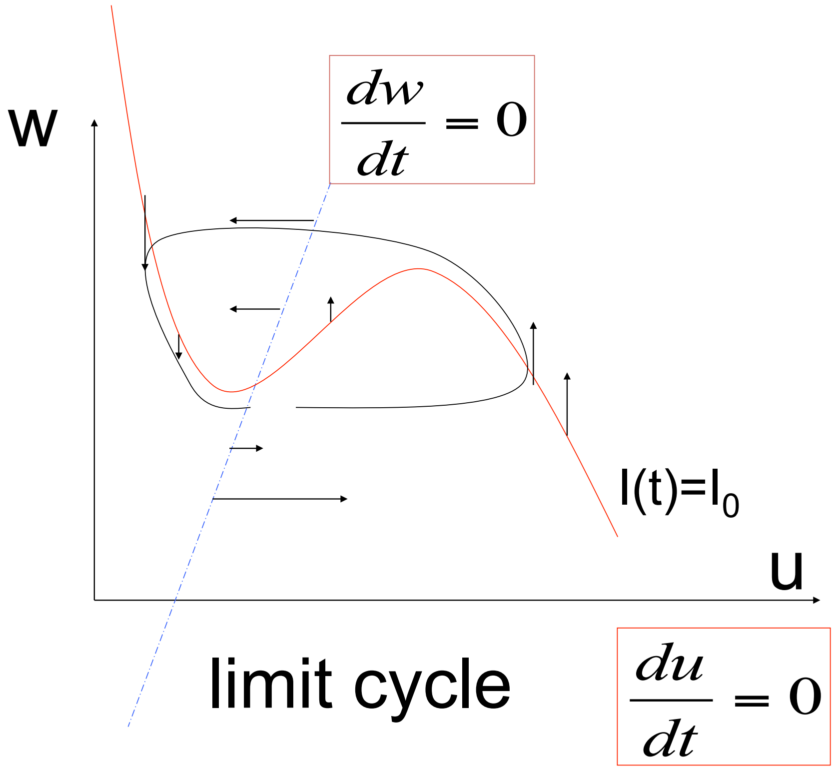
stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

-unstable fixed point
-closed boundary
  with arrows pointing inside

⟶ limit cycle

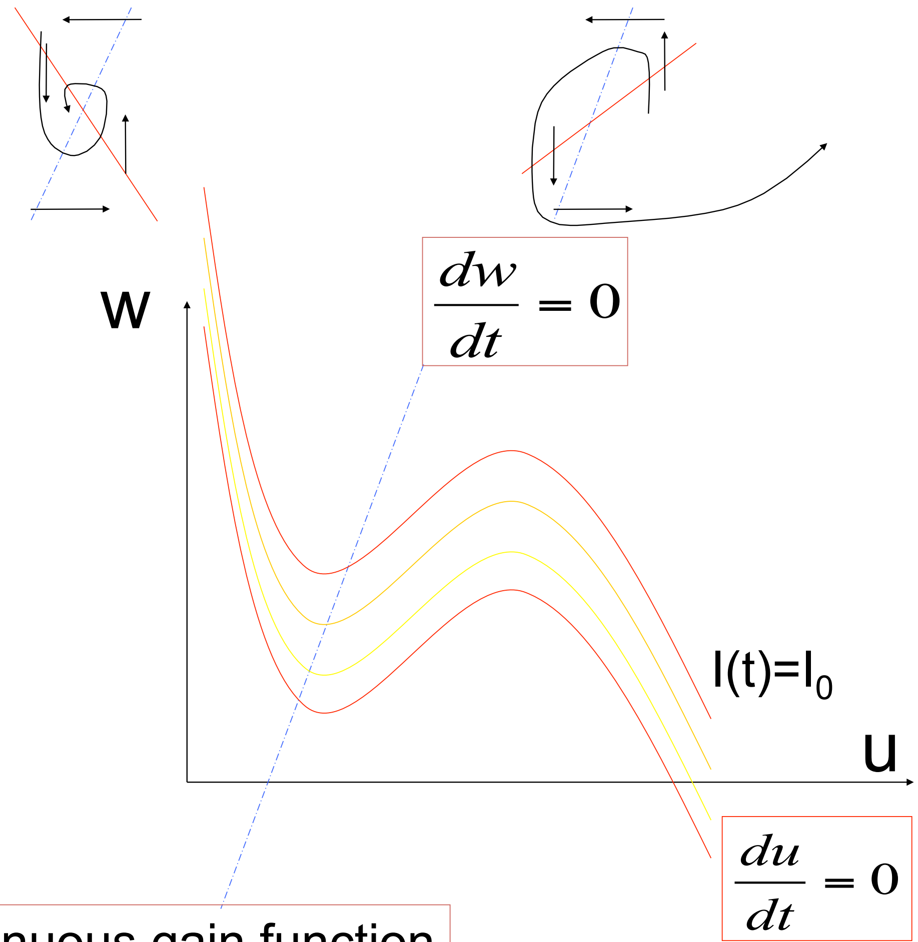


Type II Model
constant input

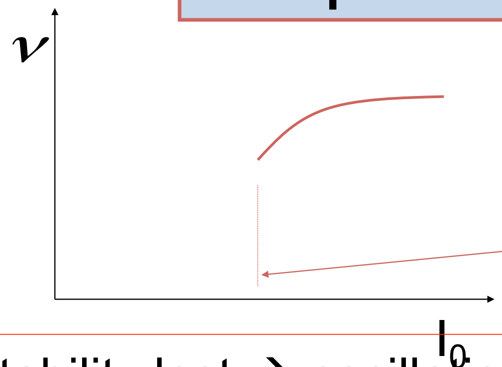
stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$



Hopf bifurcation

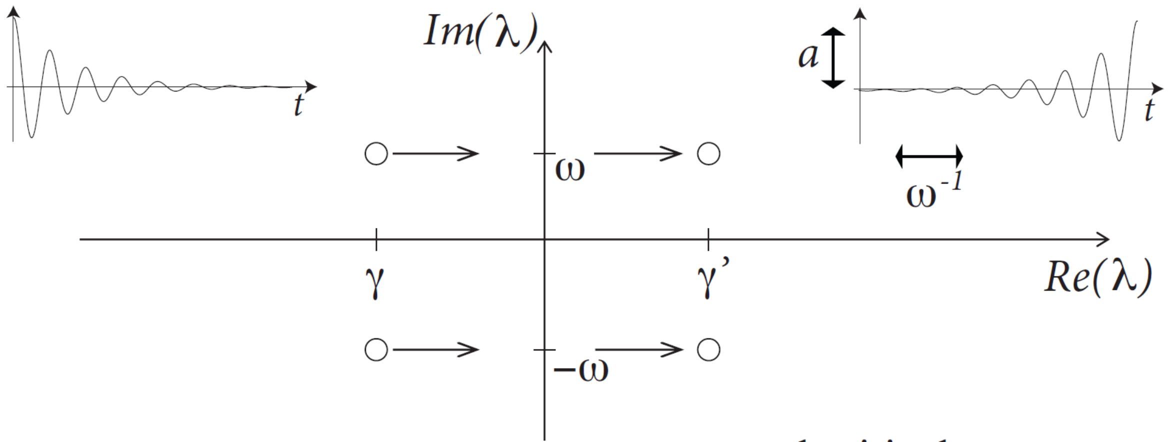


Discontinuous gain function

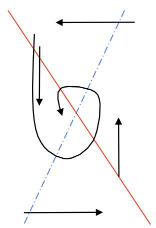
Stability lost → oscillation with finite frequency

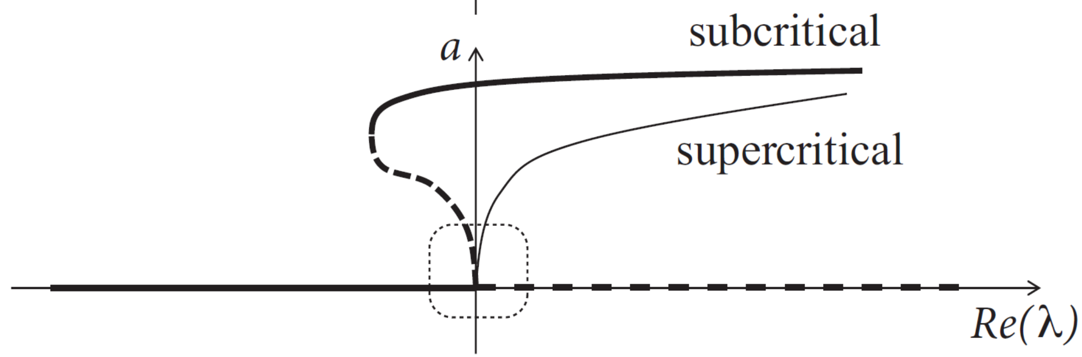
Neuronal Dynamics – 4.4. Hopf bifurcation

$$\lambda = \gamma + i\omega$$

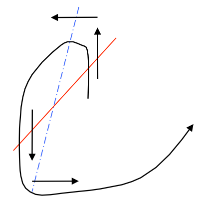


$\gamma < 0$

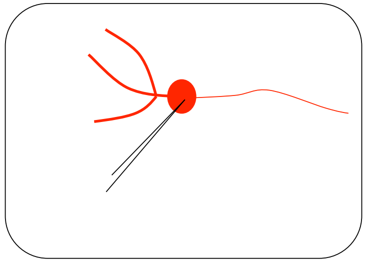




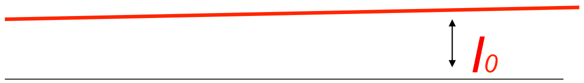
$\gamma > 0$

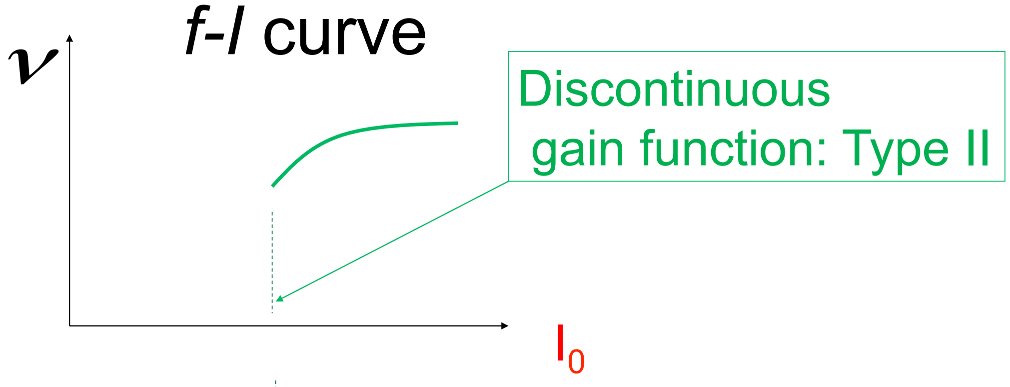


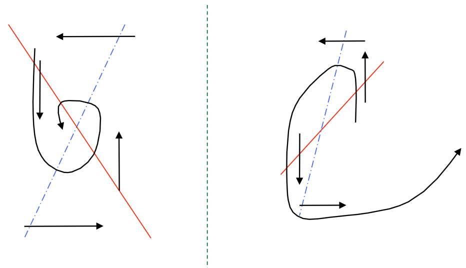
Neuronal Dynamics – 4.4. Hopf bifurcation: *f-I* -curve



ramp input/
constant input



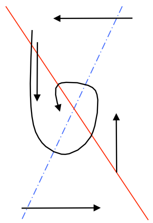


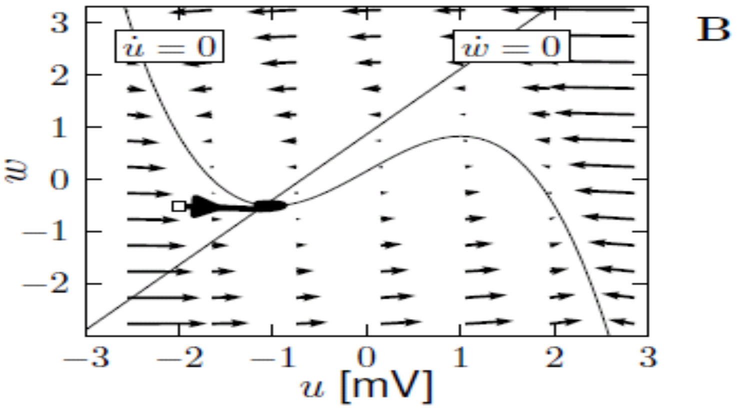


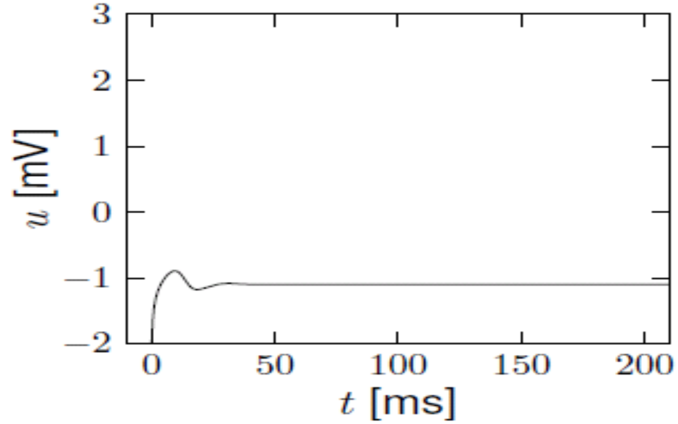
Stability lost → oscillation with finite frequency

FitzHugh-Nagumo: type II Model – Hopf bifurcation

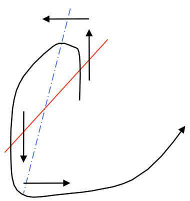
I=0

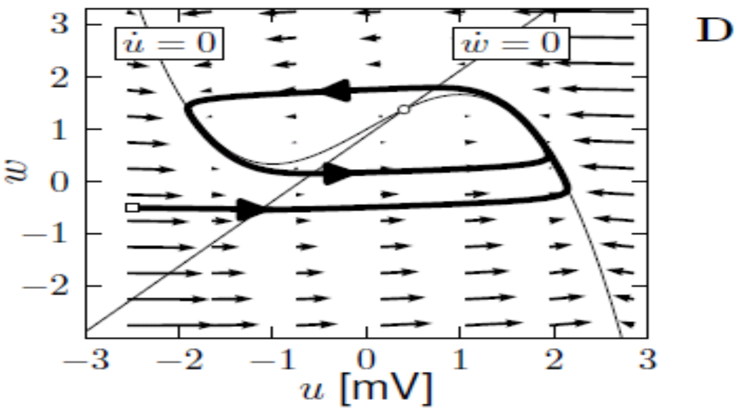


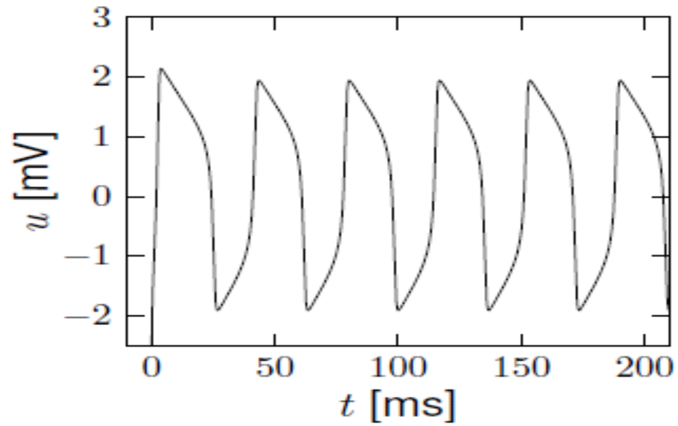




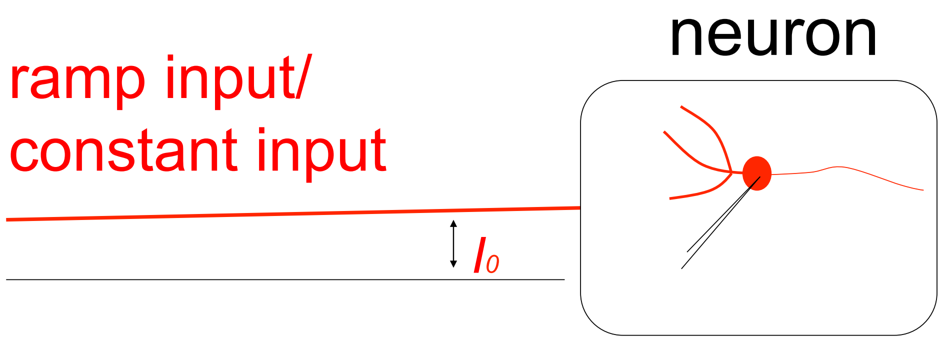
$I > I_c$



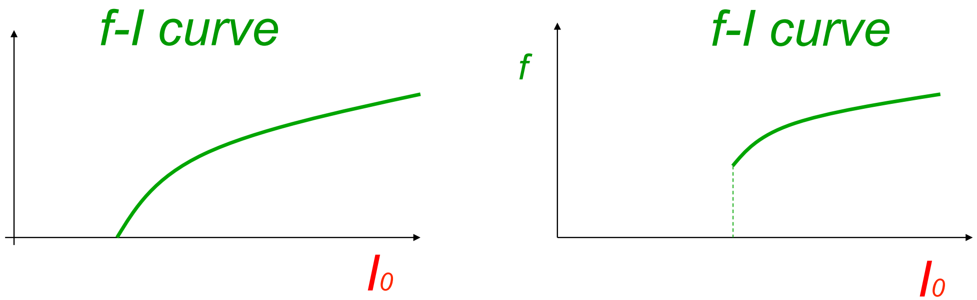




Neuronal Dynamics – 4.4. Type I and II Neuron Models



Type I and type II models



Neuronal Dynamics – 4.4. Type I and II Neuron Models

type I Model: 3 fixed points

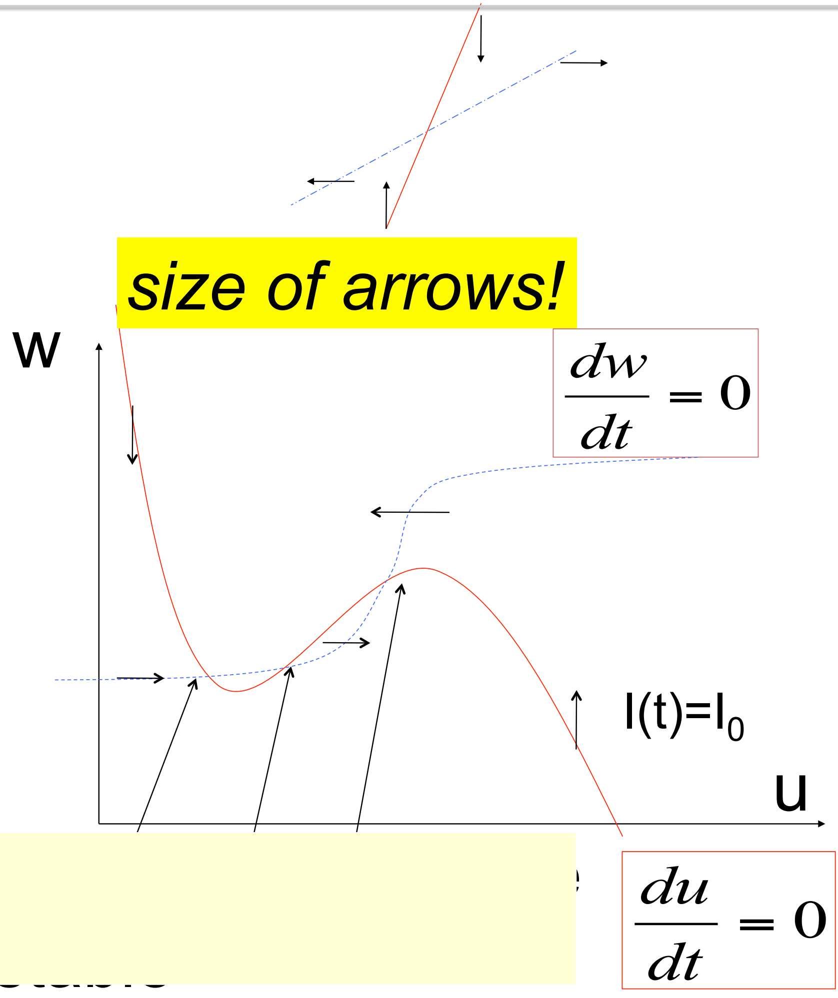
stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

apply constant stimulus I_0

Saddle-node bifurcation



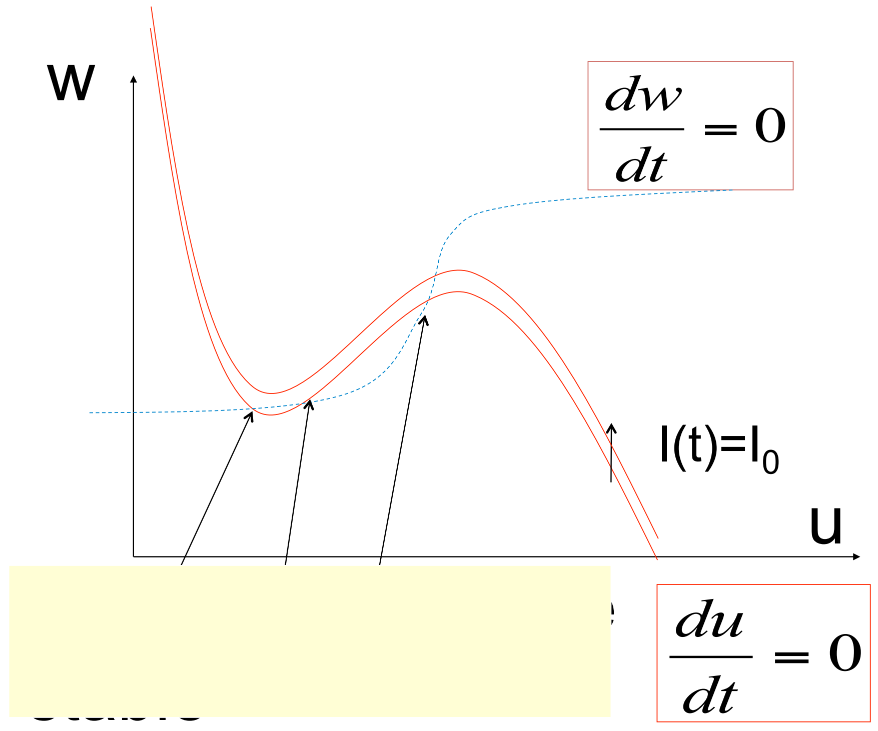
Saddle-node bifurcation

stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

flow arrows

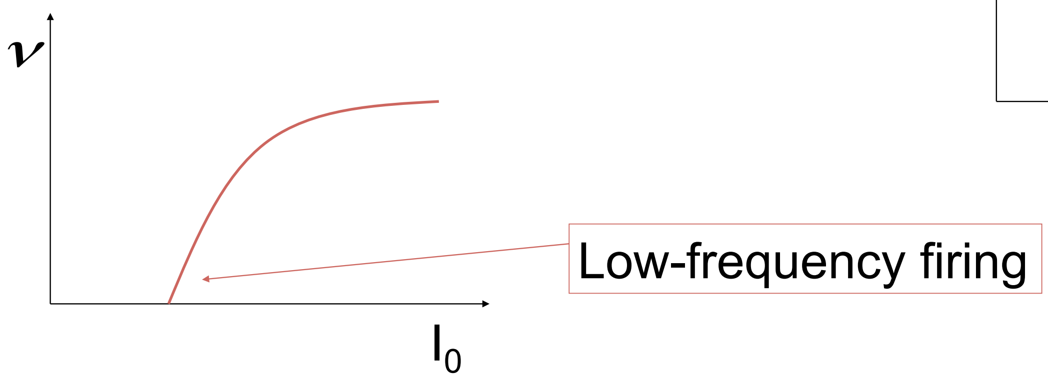


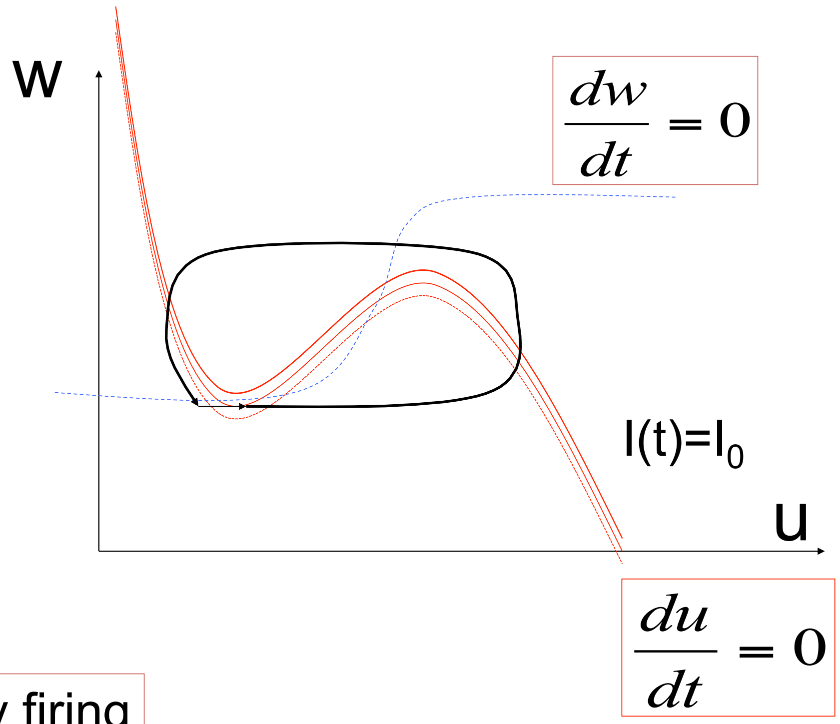
type I Model – constant input

stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

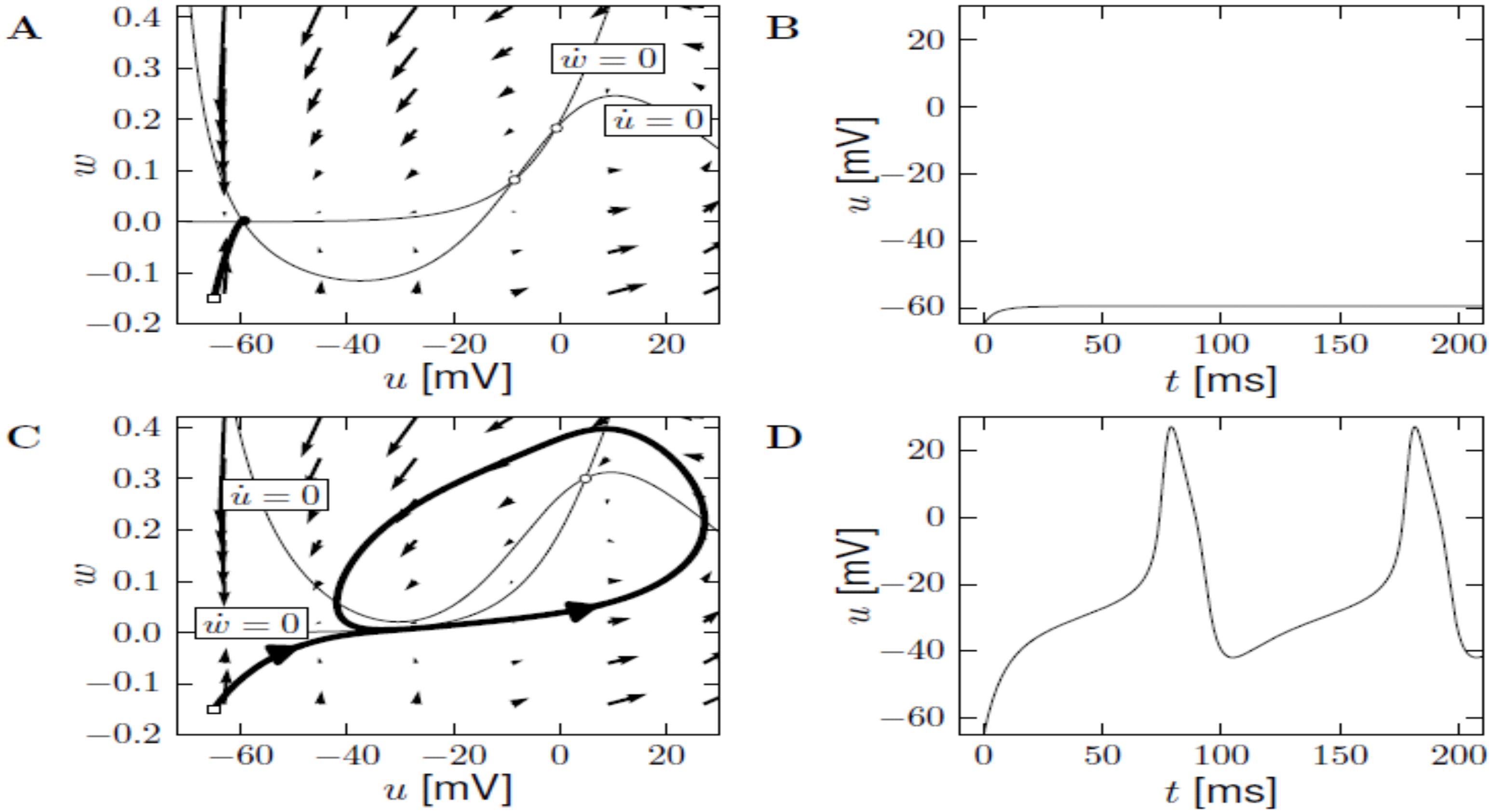




Morris-Lecar, type I Model – constant input

I=0

$I > I_c$



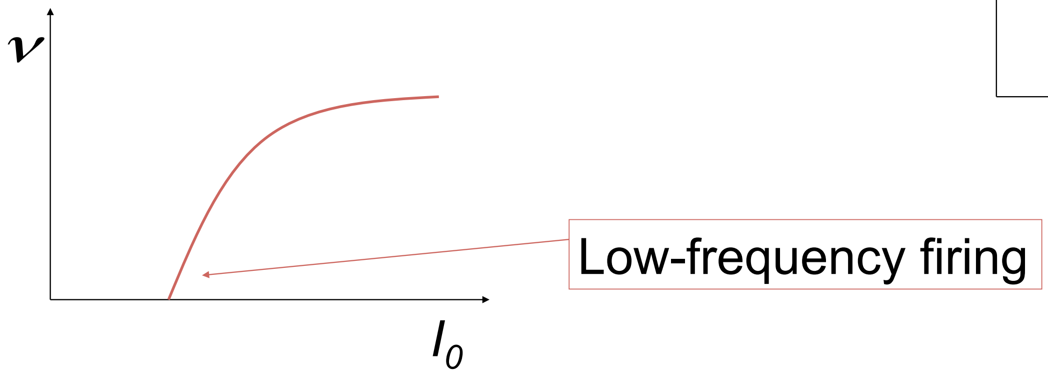
type I Model – constant input

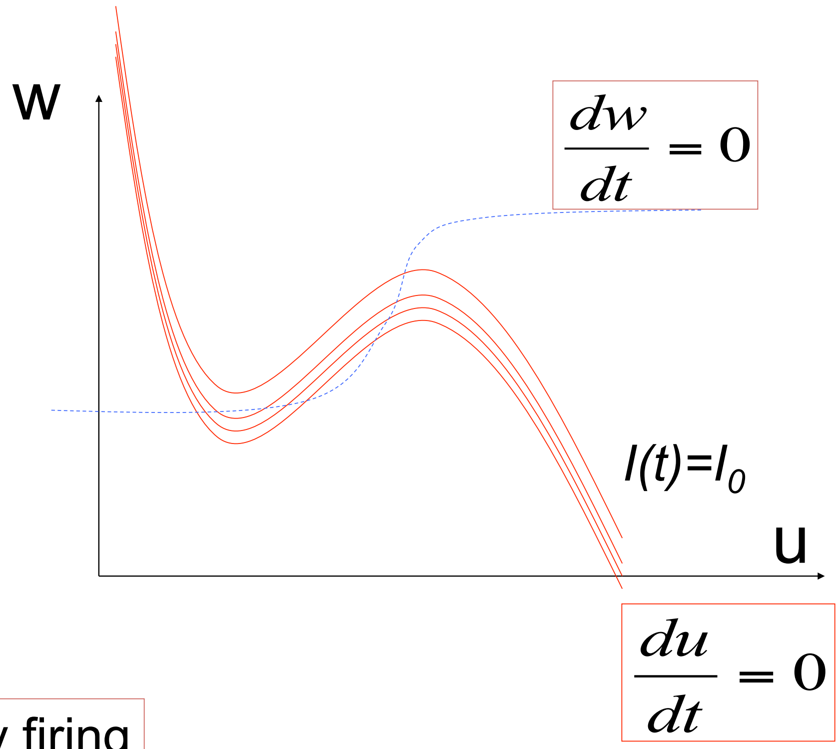
stimulus

$$\tau \frac{du}{dt} = F(u,w) + I(t)$$

$$\frac{dw}{dt} = -\frac{w - w_0(u)}{\tau_{eff}(u)}$$

$$w_0(u) = 0.5[1 + \tanh(\tfrac{u-\theta}{d})]$$





Type I and type II models

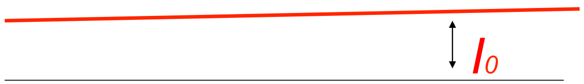
Response at firing threshold?

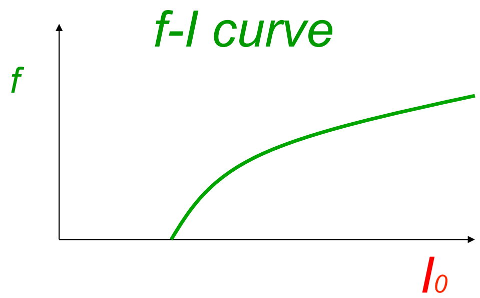
Type I | type II

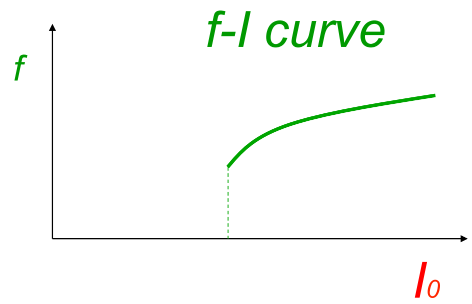
Saddle-Node
Onto limit cycle

For example:
Subcritical Hopf

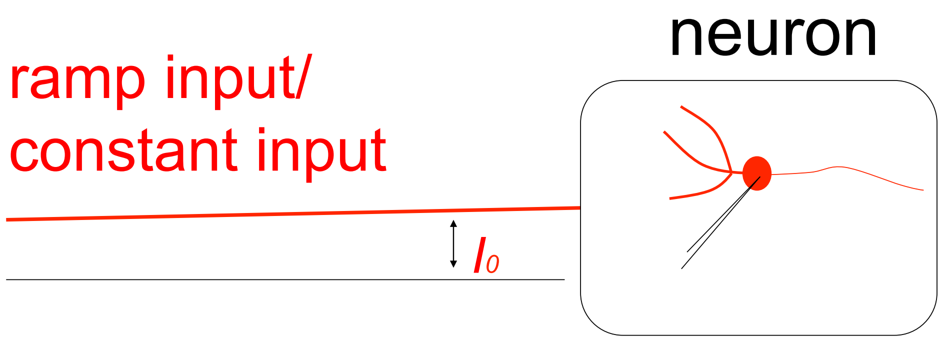
ramp input/
constant input







Neuronal Dynamics – 4.4. Type I and II Neuron Models



Type I and type II models