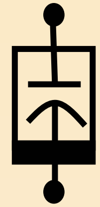
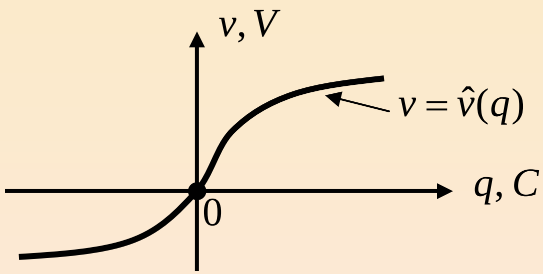
CAPACITOR



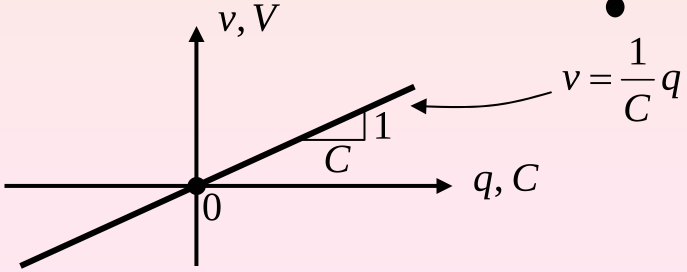


Element Law : $\boxed{v = \hat{v}(q)}$

where **charge**

$$q(t) \triangleq \int_{-\infty}^{t} i(\tau)\, d\tau$$

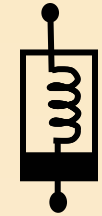
Special case : Linear Capacitor  C

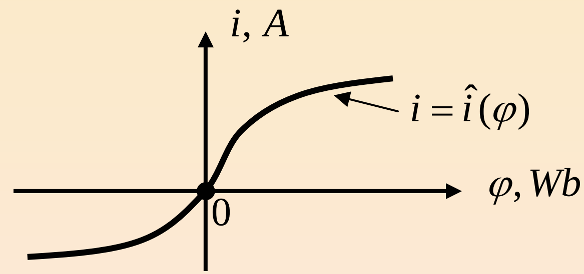


Element Law : $q = C\, v$

$$\boxed{i(t) = C\,\frac{dv(t)}{dt}}$$

INDUCTOR



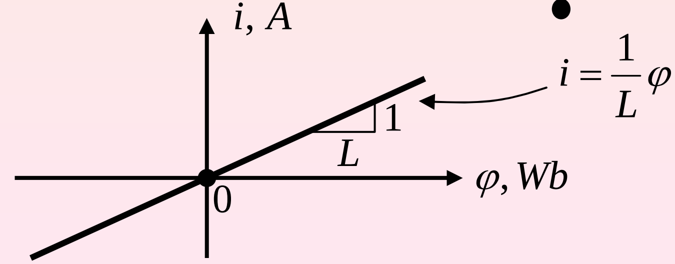


Element Law : $\boxed{i = \hat{i}(\varphi)}$

where **flux**

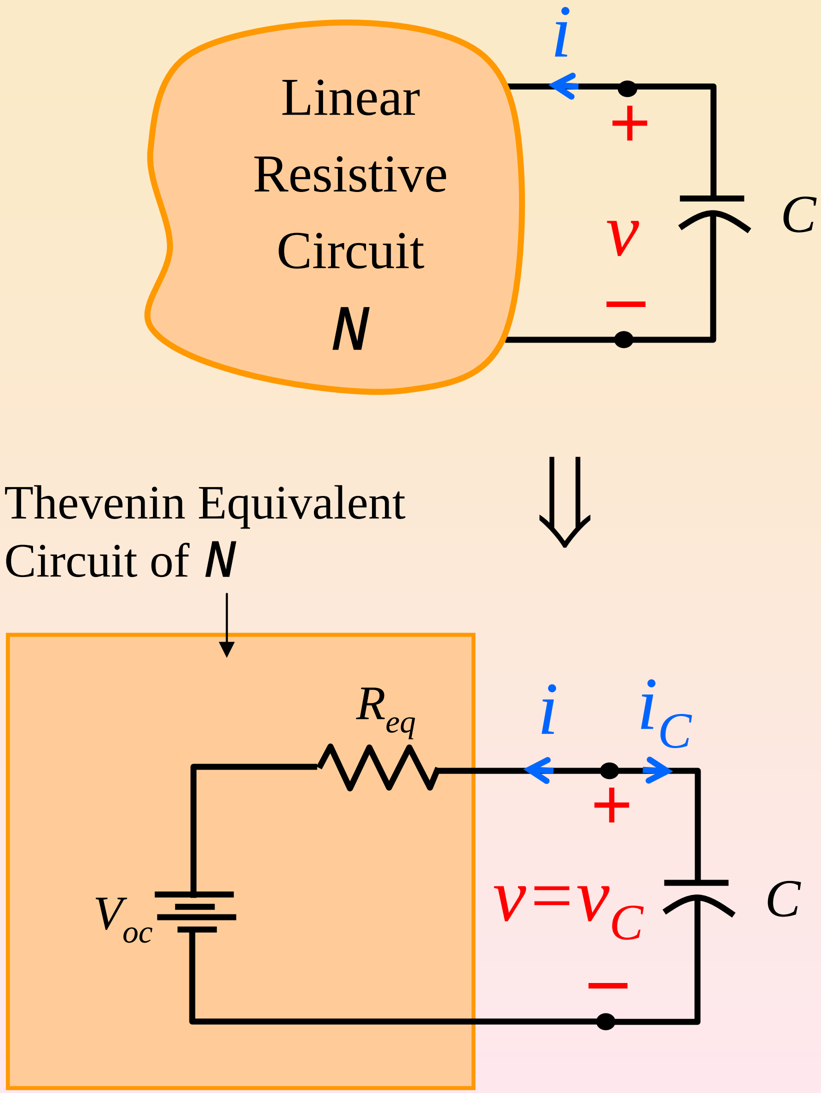
$$\varphi(t) \triangleq \int_{-\infty}^{t} v(\tau)\, d\tau$$

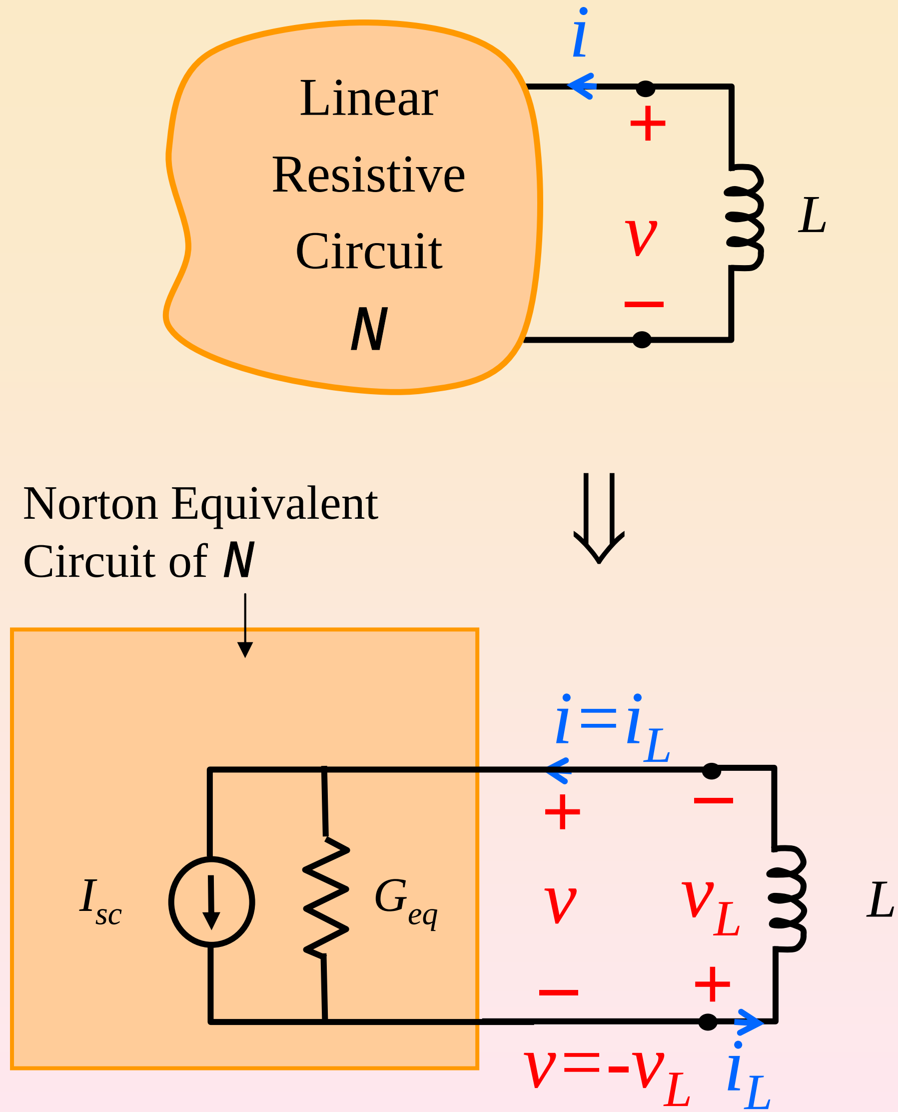
Special case : Linear Inductor  L



Element Law : $\varphi = L\, i$

$$\boxed{v(t) = L\,\frac{di(t)}{dt}}$$

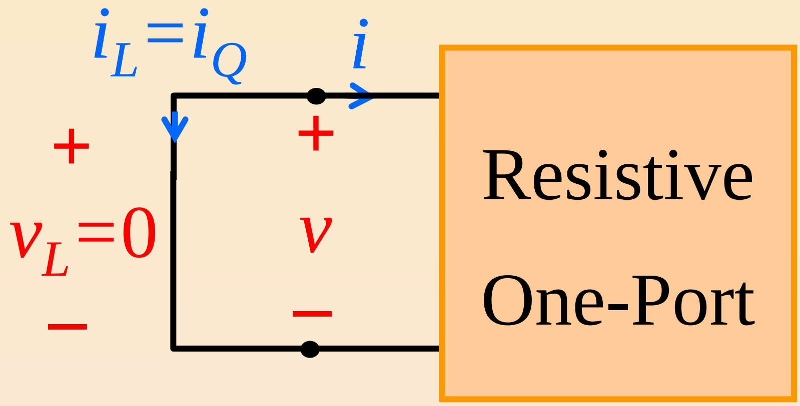




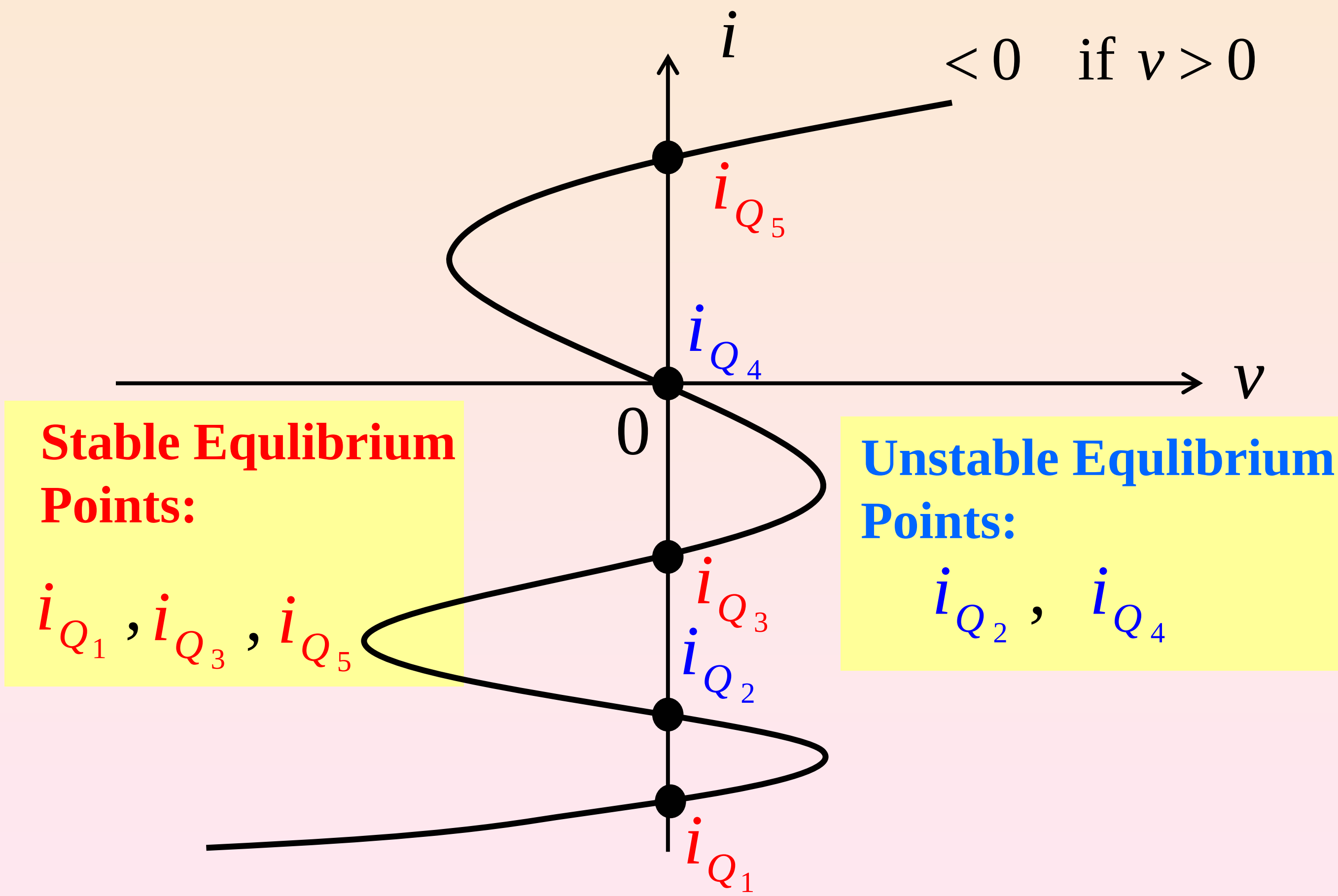
$$\frac{dv_C}{dt} = -\frac{v_C}{R_{eq}C} + \frac{V_{oc}}{R_{eq}C}$$

$$\frac{di_L}{dt} = -\frac{i_L}{G_{eq}L} + \frac{I_{sc}}{G_{eq}L}$$

Equilibrium Points



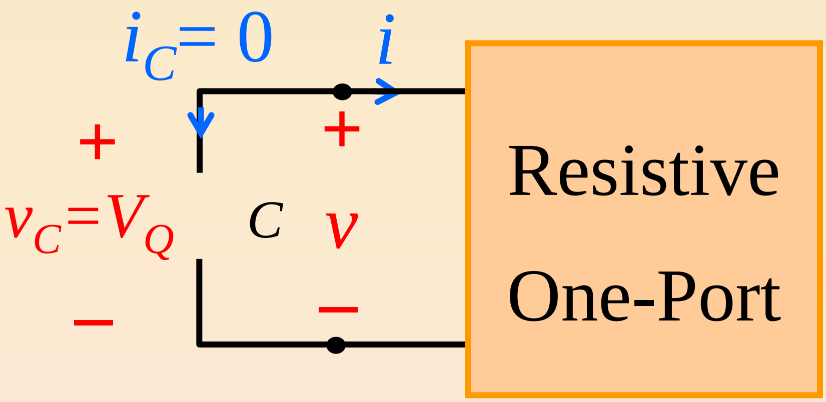
$$\frac{d\,i}{d\,t} = \frac{-v}{L} \begin{cases} > 0 & \text{if } v < 0 \\ = 0 & \text{if } v = 0 \\ < 0 & \text{if } v > 0 \end{cases}$$



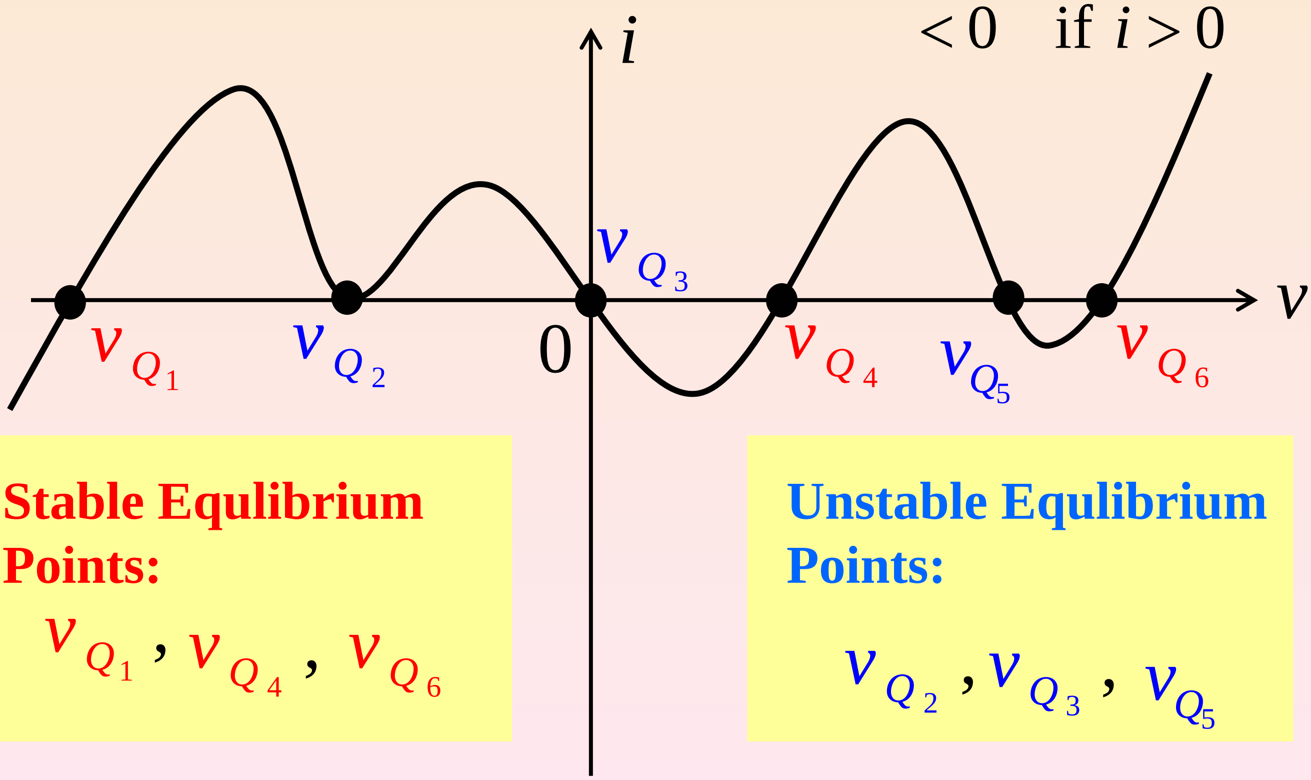
Conclusion

Each short-circuit inductor current i_{Q_j} is an **Equilibrium Point** of this *RL* circuit.

Equilibrium Points



$$\frac{dv}{dt} = \frac{-i}{C} \begin{cases} > 0 & \text{if } i < 0 \\ = 0 & \text{if } i = 0 \\ < 0 & \text{if } i > 0 \end{cases}$$



Stable Equlibrium Points:

$v_{Q_1}, v_{Q_4}, v_{Q_6}$

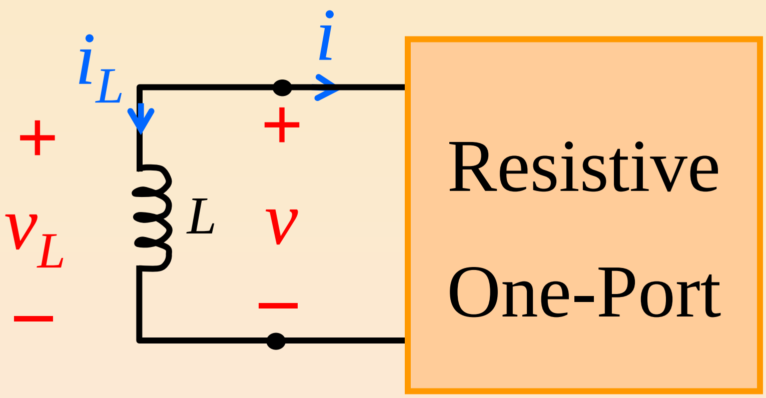
Unstable Equlibrium Points:

$v_{Q_2}, v_{Q_3}, v_{Q_5}$

Conclusion

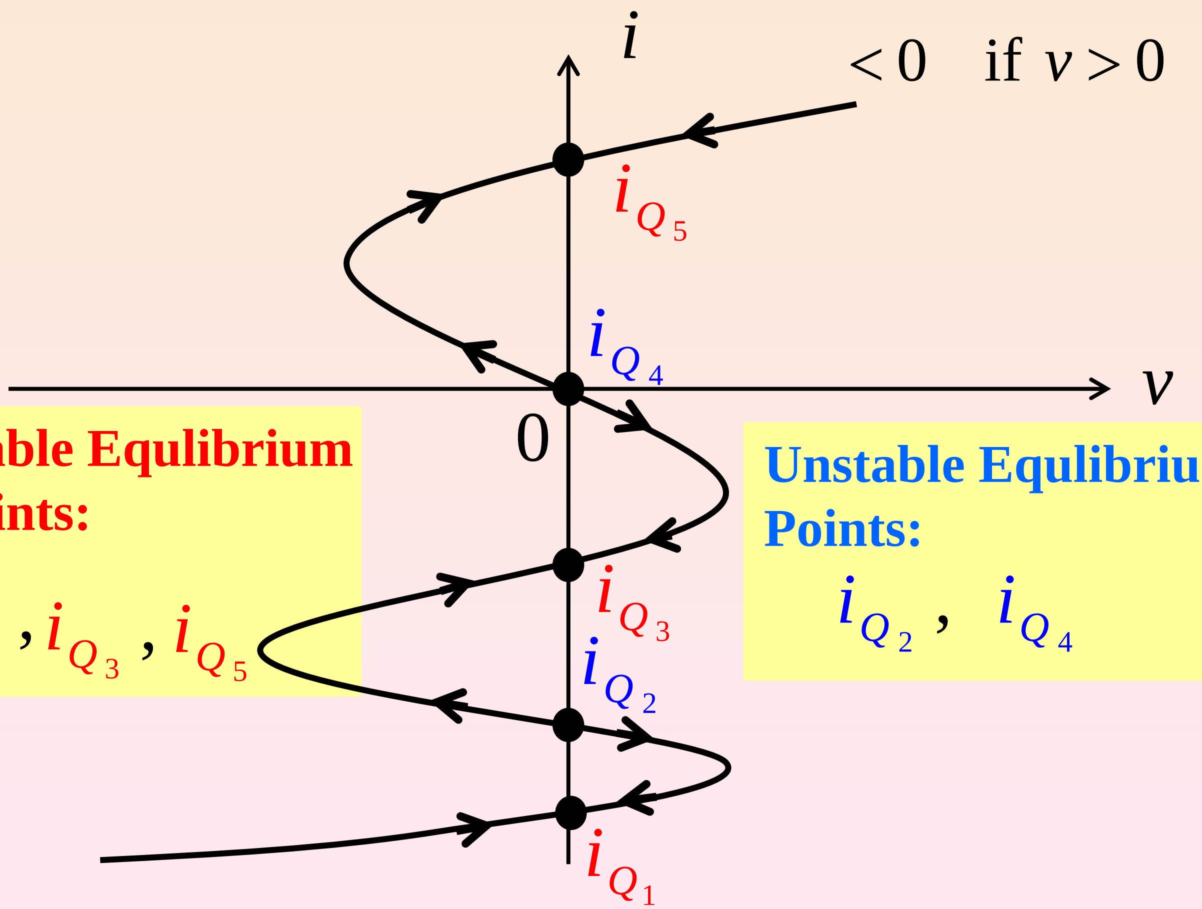
Each open-circuit capacitor voltage v_{Q_j} is an **Equilibrium Point** of this *RC* circuit.

Equilibrium Points



$$\frac{di}{dt} = \frac{-v}{L}$$

$$\begin{aligned} &> 0 \quad \text{if } v < 0 \\ &= 0 \quad \text{if } v = 0 \\ &< 0 \quad \text{if } v > 0 \end{aligned}$$



Stable Equlibrium Points:

$i_{Q_1}, i_{Q_3}, i_{Q_5}$

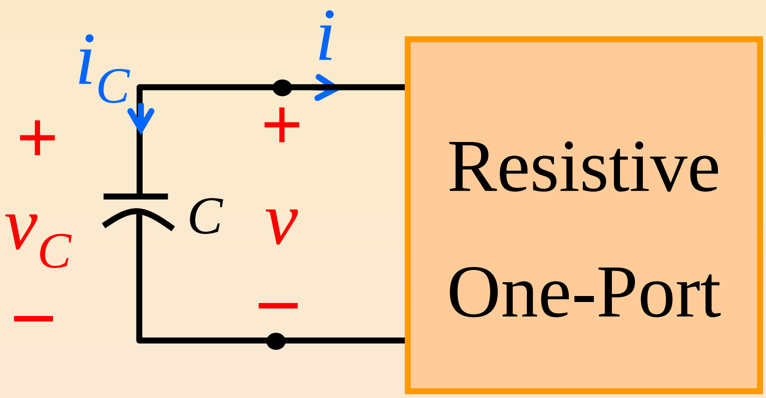
Unstable Equlibrium Points:

$i_{Q_2}, \; i_{Q_4}$

Conclusion

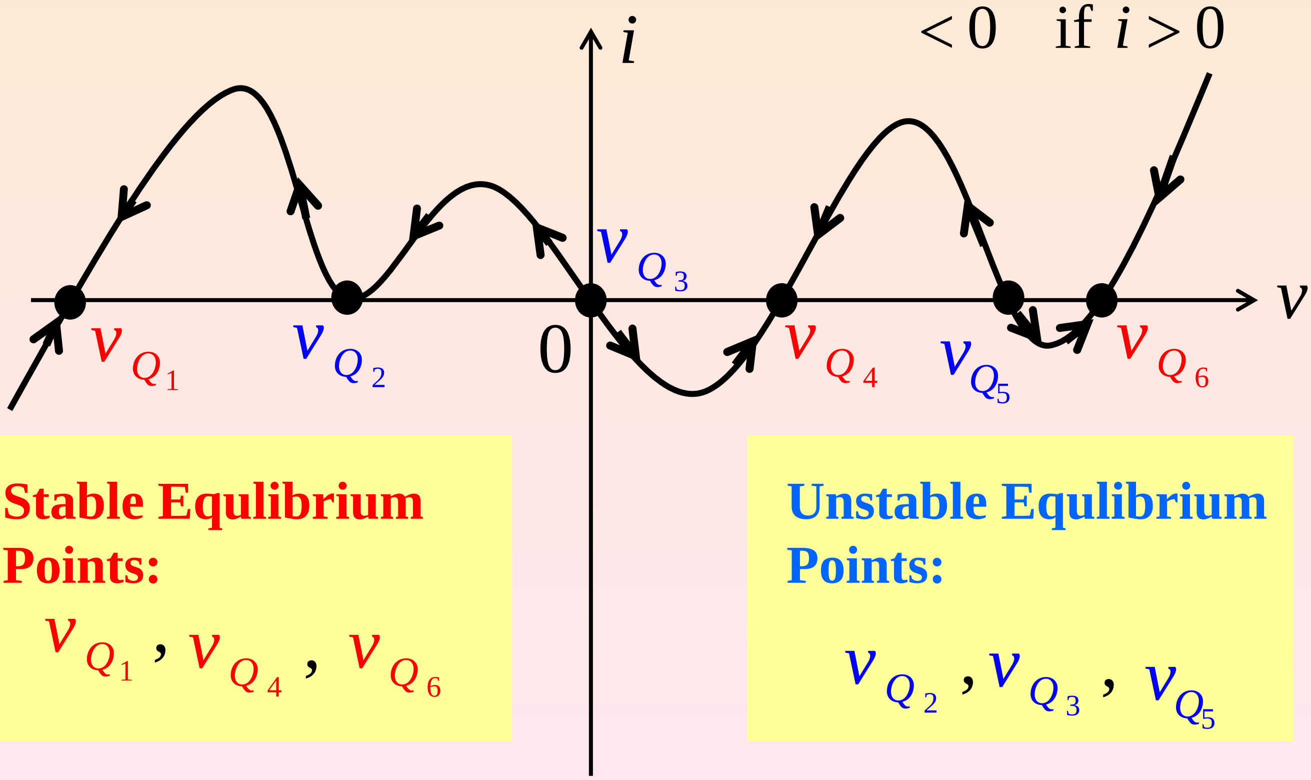
Each short-circuit inductor current i_{Q_j} is an **Equilibrium Point** of this *RL* circuit.

Equilibrium Points



$$\frac{dv}{dt} = \frac{-i}{C}$$

$$\begin{aligned} &> 0 \quad \text{if } i < 0 \\ &= 0 \quad \text{if } i = 0 \\ &< 0 \quad \text{if } i > 0 \end{aligned}$$



Stable Equlibrium Points:

v_{Q_1}, v_{Q_4}, v_{Q_6}

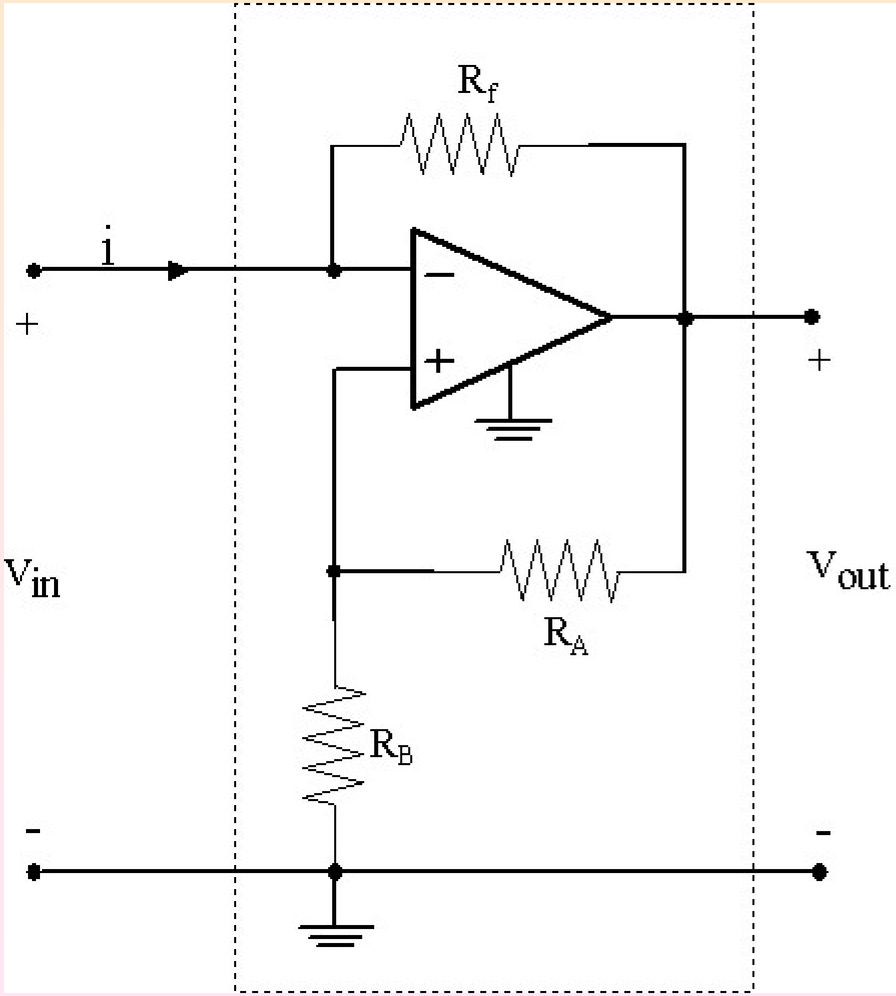
Unstable Equlibrium Points:

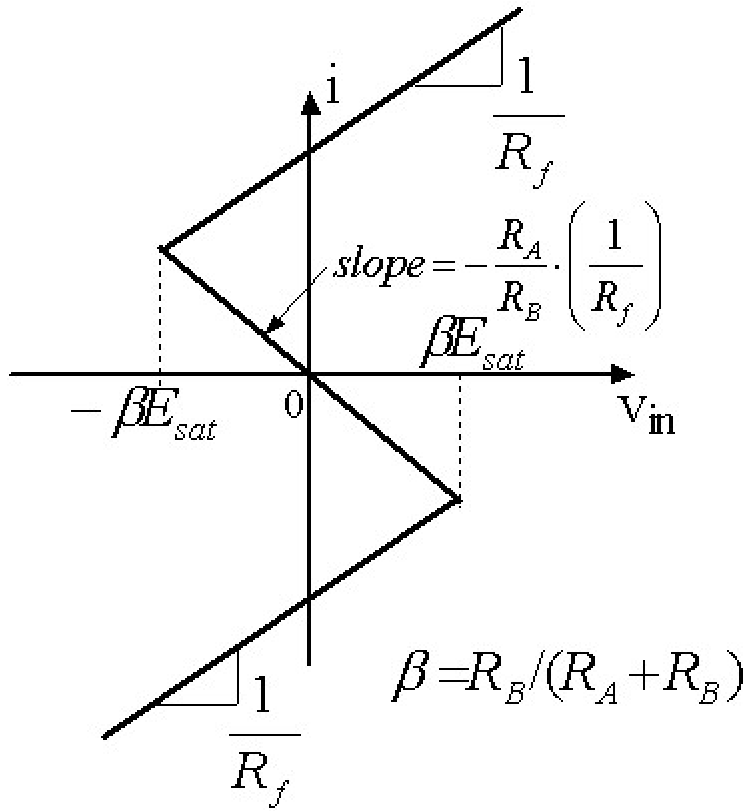
v_{Q_2}, v_{Q_3}, v_{Q_5}

Conclusion

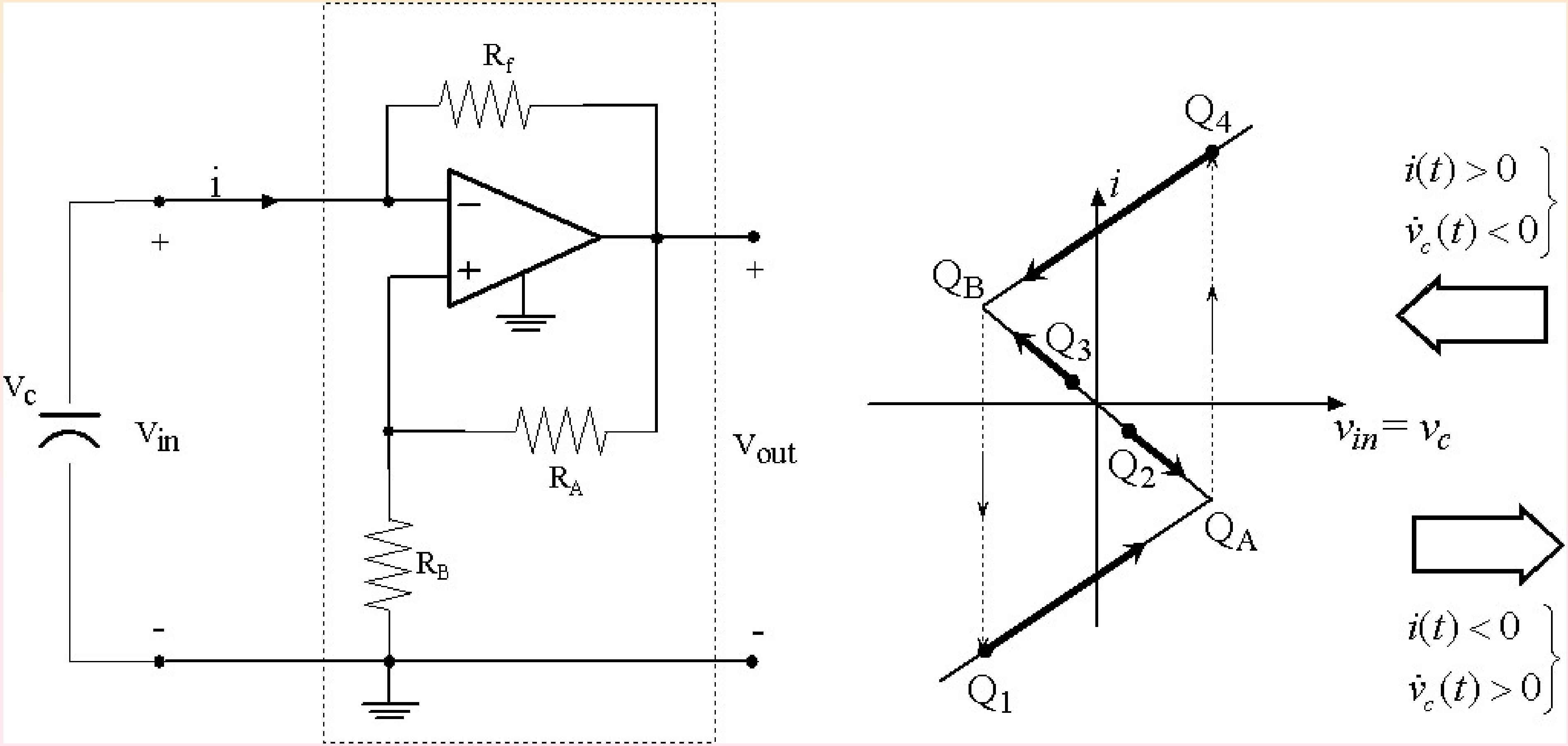
Each open-circuit capacitor voltage v_{Q_j} is an **Equilibrium Point** of this *RC* circuit.

Negative Resistance Converter and its Driving-Point Characteristic

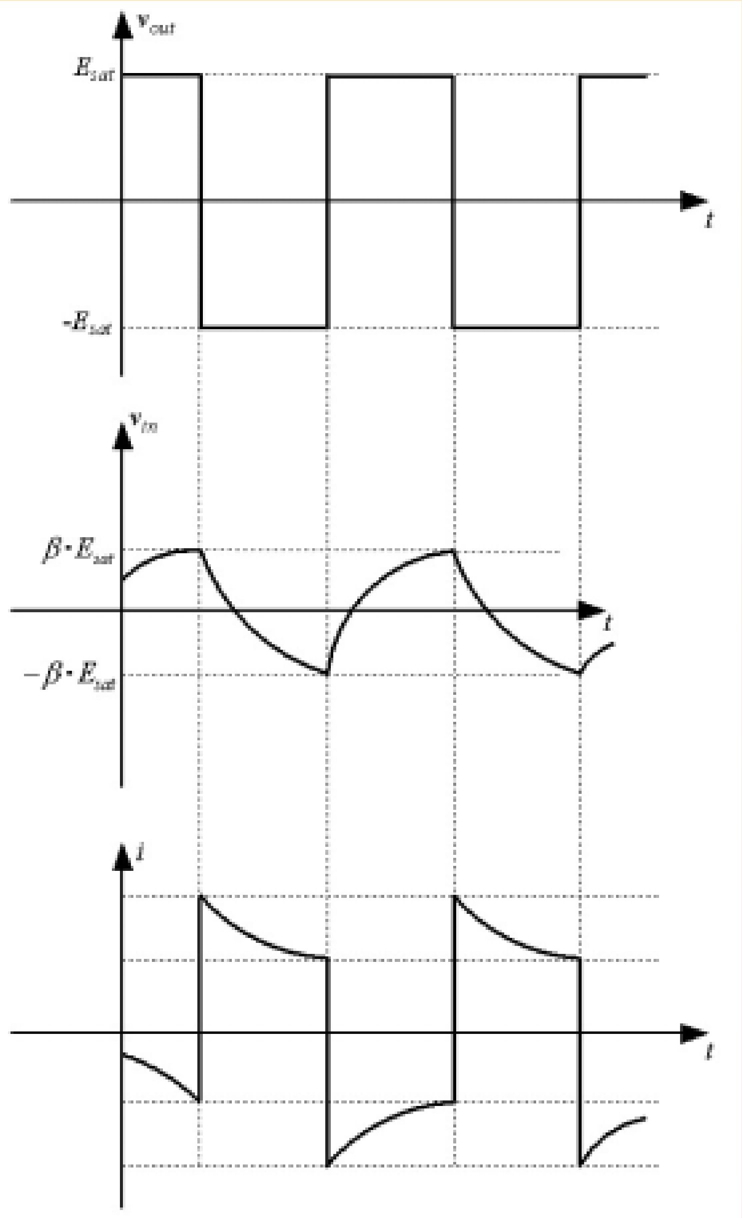




An Astable RC op-amp Circuit and its Driving-Point Characteristic



Waveforms of the Astable RC op-amp Circuit

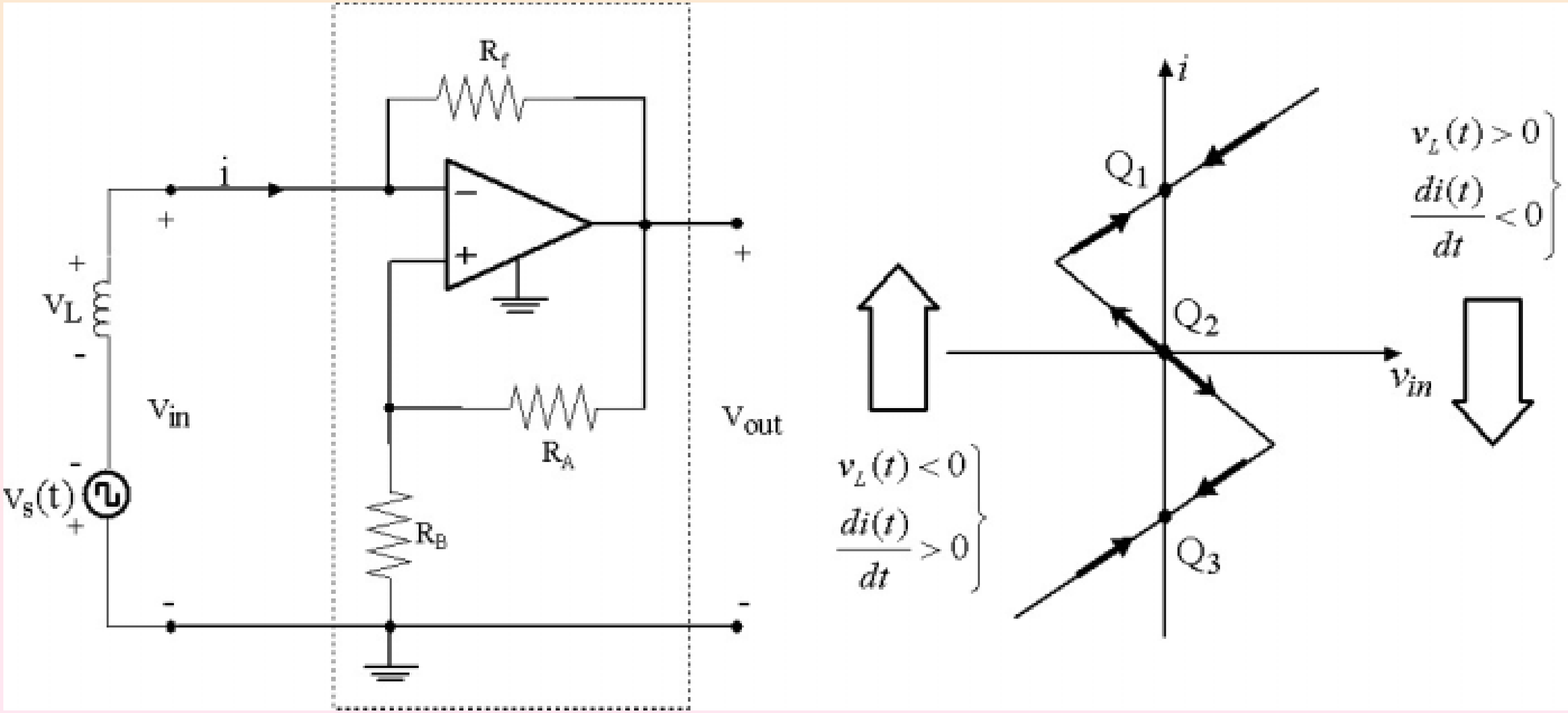


Output Voltage

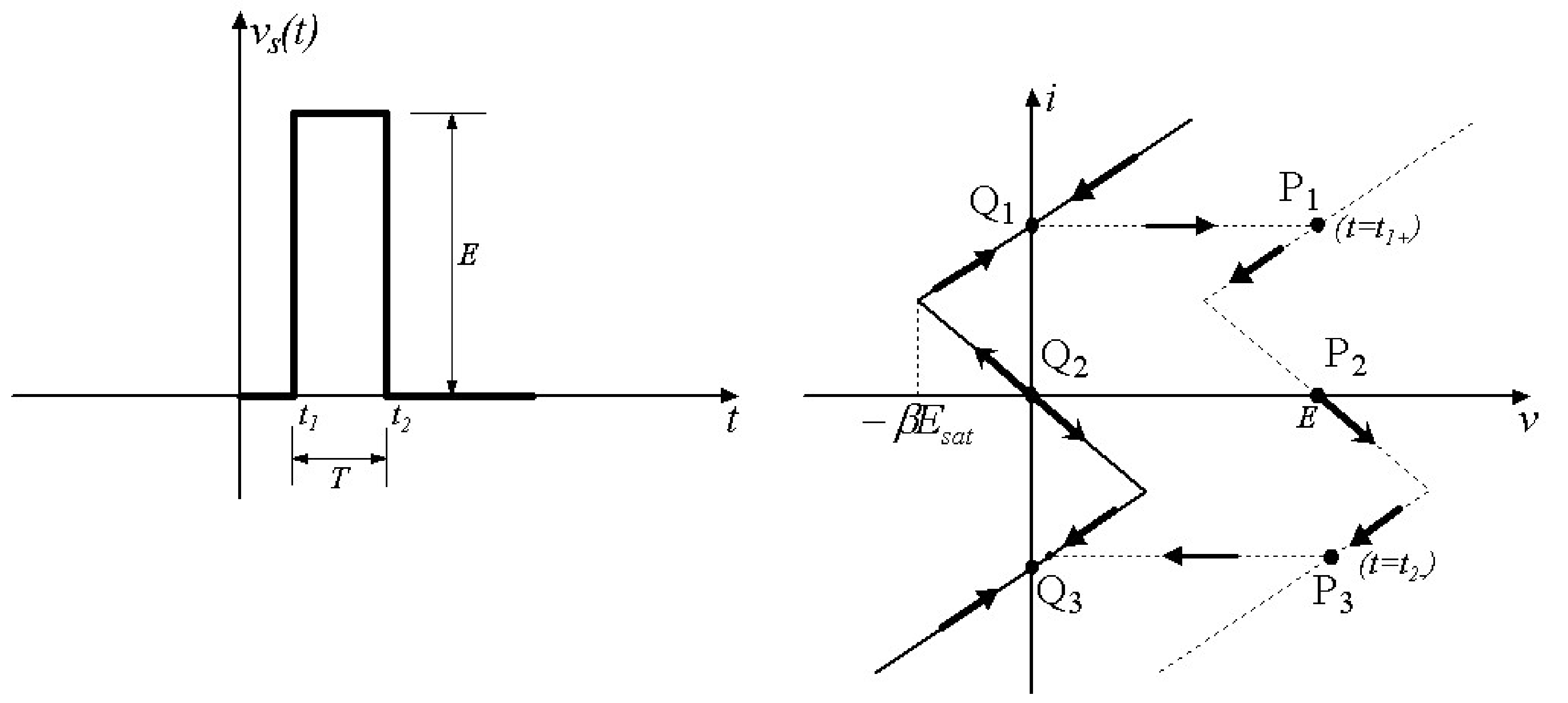
Input Voltage

Input Current

A Bi-stable op-amp Circuit and its Driving Point Characteristic

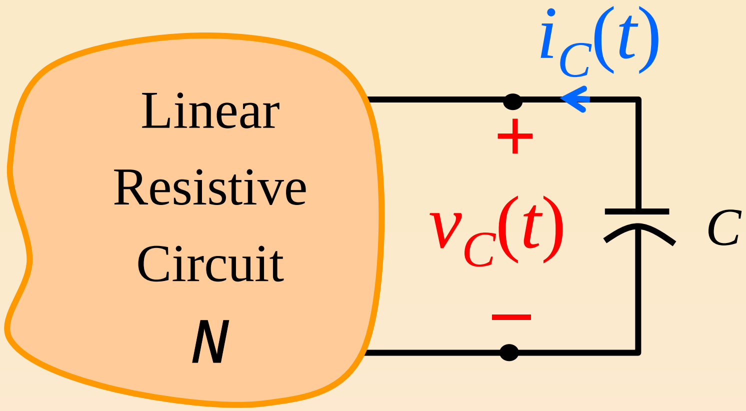


Dynamic Route of the Bi-stable op-amp Circuit Corresponding to a Square Pulse Triggering Signal



Impasse Point

A point Q is called an **impasse point** whenever a **dynamic route** starting from $t = t_j$ reaches Q at some **finite** time $t = t_k > t_j$ and can ***not*** be continued for $t > t_k$ without violating the capacitor (resp., inductor) element law.



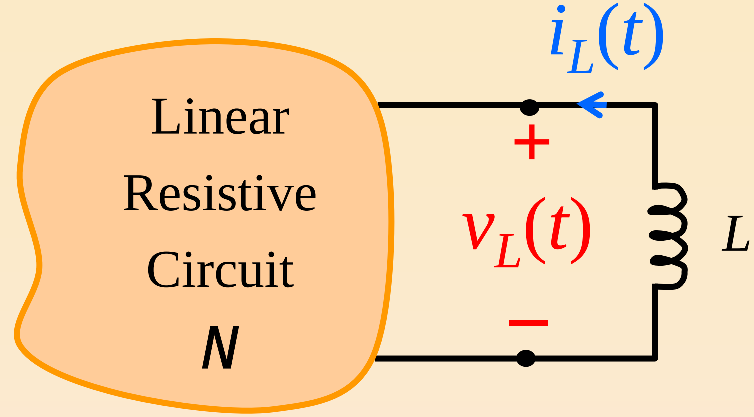
Capacitor Voltage Continuity Theorem

The **voltage** $v_C(t)$ across a **capacitor** can *not* change abruptly at any time $t = t_k$, provided

$$i_C(t_k) \neq \pm\infty$$

namely,

$$\boxed{v_C(t_k^{+}) = v_C(t_k^{-})}$$



Inductor Current Continuity Theorem

The **current** $i_L(t)$ through an **inductor** can *not* change abruptly at any time $t = t_k$, provided

$$v_L(t_k) \neq \pm\infty$$

namely,

$$\boxed{i_L(t_k^{+}) = i_L(t_k^{-})}$$

Proof.

$$i_C(t) = C\frac{dv_C(t)}{dt}$$

$$\Rightarrow \quad v_C(t) = \frac{1}{C}\int_{-\infty}^{t} i_C(\tau)\,d\tau$$

$$v_C(t_k^- + \Delta t) = \underbrace{\frac{1}{C}\int_{-\infty}^{t_k^-} i_C(\tau)\,d\tau}_{v_C(t_k^-)} + \underbrace{\frac{1}{C}\int_{t_k^-}^{t_k^- + \Delta t} i_C(\tau)\,d\tau}_{\mathbf{A}_\Delta}$$

$$= v_C(t_k^-) + \frac{1}{C}(\mathbf{A}_\Delta)$$

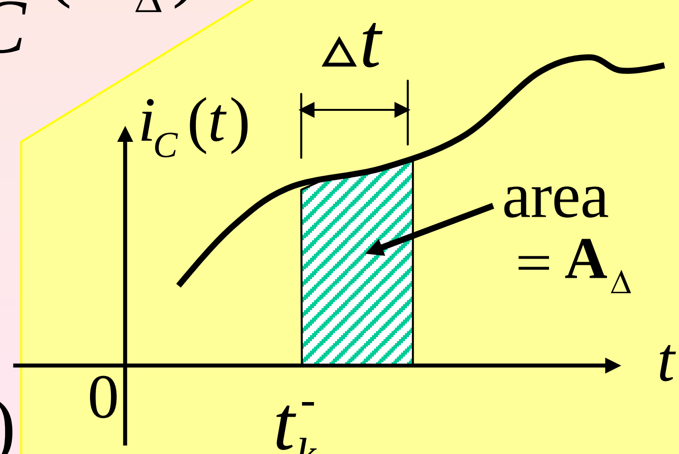
as $\Delta t \to 0$,

$t_k^- + \Delta t \to t_k^+$ and

$\mathbf{A}_\Delta \to 0$

(provided $i_C(t_k) \neq \pm\infty$)

$$\therefore \boxed{v_C(t_k^+) = v_C(t_k^-)}$$



$$\int_{t_k^-}^{t_k^- + \Delta t} i_C(t)\,dt = \mathbf{A}_\Delta$$

Jump Rule

Capacitor Current Jump Rule

Upon reaching an **impasse point** Q at $t = t_k^-$ in an ***RC* circuit**, the **dynamic route jumps abruptly** to a point on the *v*-*i* curve at $t = t_k^+$ such that

$$\boxed{v_C(t_k^+) = v_C(t_k^-)}$$

Inductor Voltage Jump Rule

Upon reaching an **impasse point** Q at $t = t_k^-$ in an ***RL* circuit**, the **dynamic route jumps abruptly** to a point on the *v*-*i* curve at $t = t_k^+$ such that

$$\boxed{i_L(t_k^+) = i_L(t_k^-)}$$