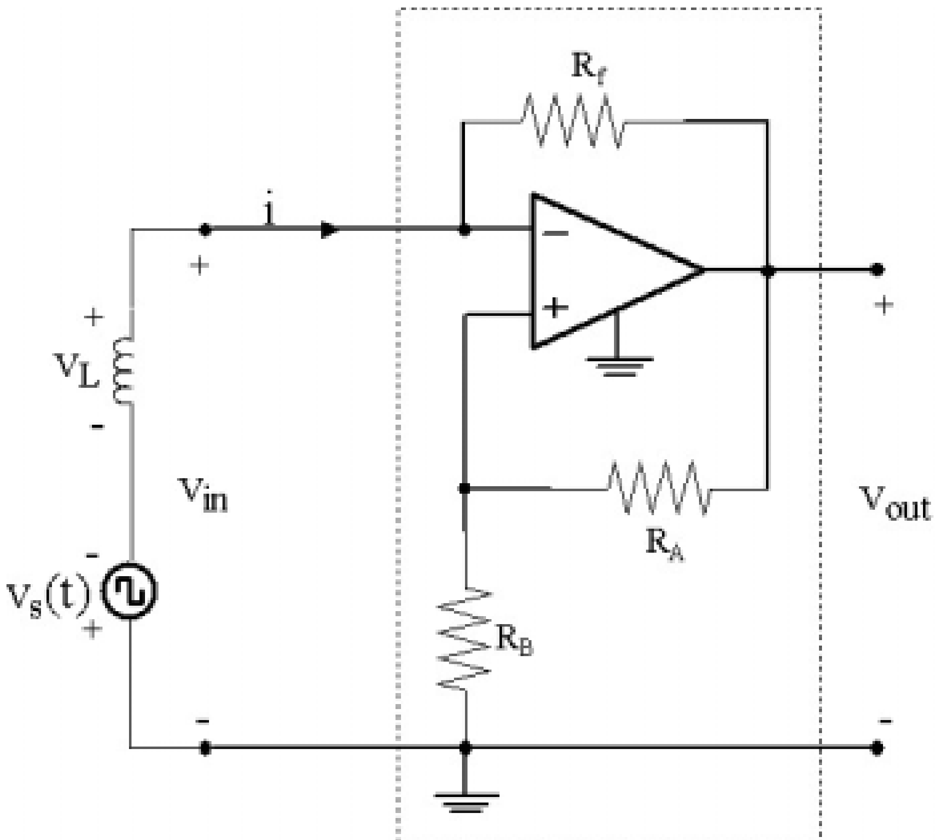
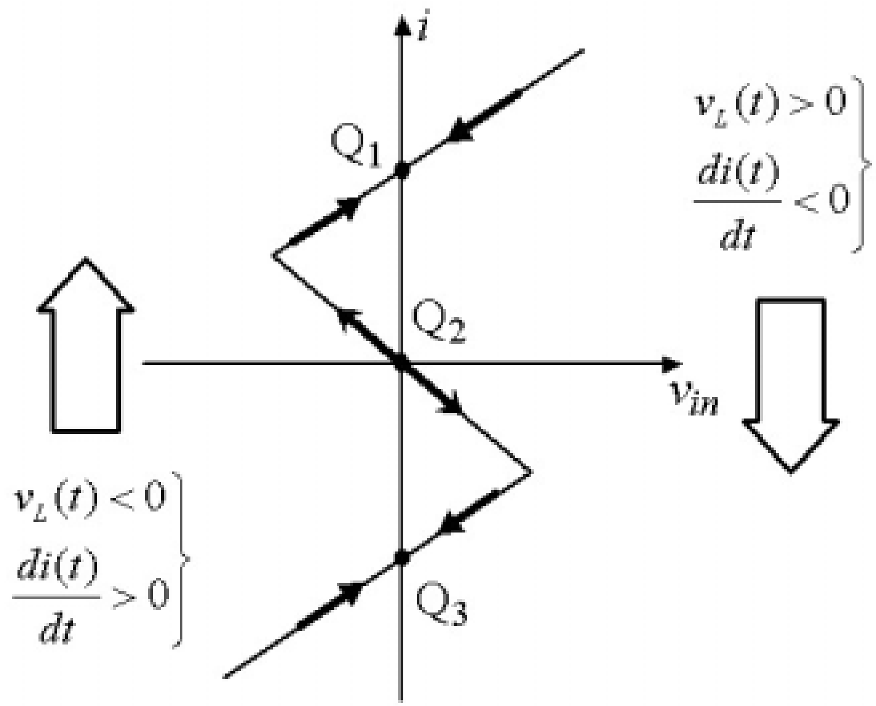
A Bi-stable op-amp Circuit and its Driving Point Characteristic





Jump Rule

Capacitor Current Jump Rule

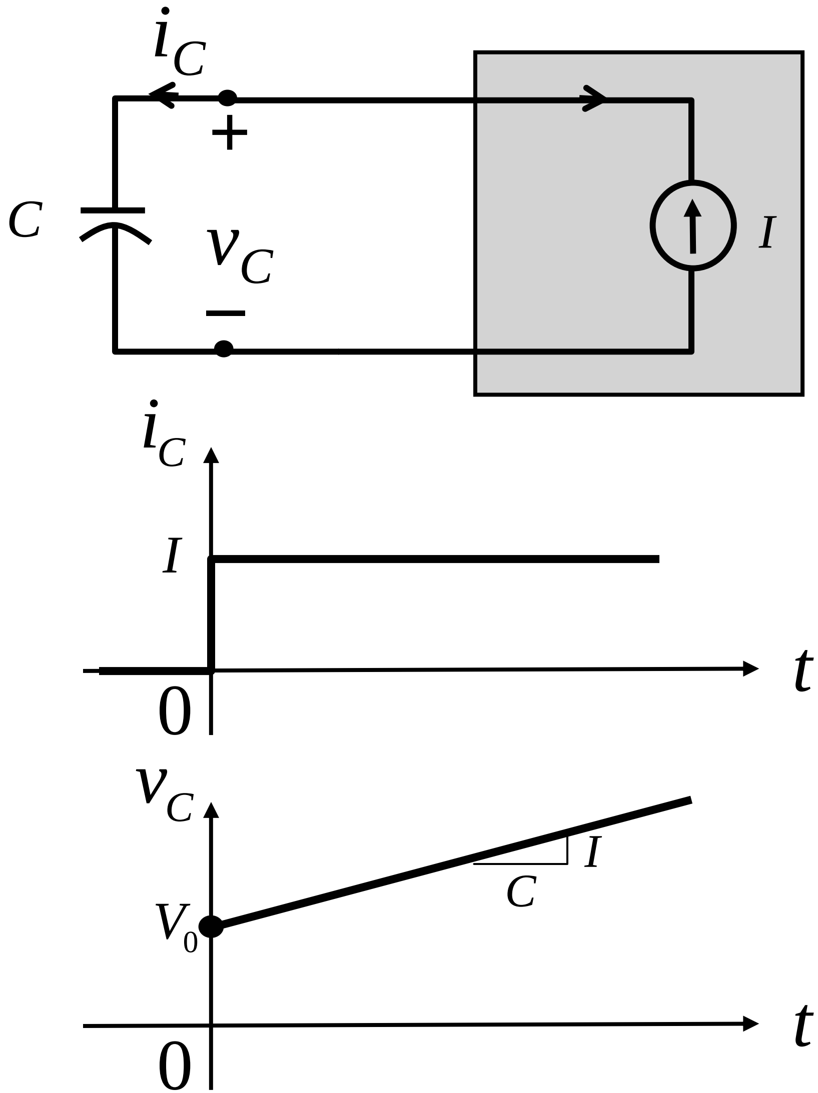
Upon reaching an **impasse point** Q at $t = t_k^-$ in an ***RC* circuit**, the **dynamic route jumps abruptly** to a point on the *v*-*i* curve at $t = t_k^+$ such that

$$v_C(t_k^+) = v_C(t_k^-)$$

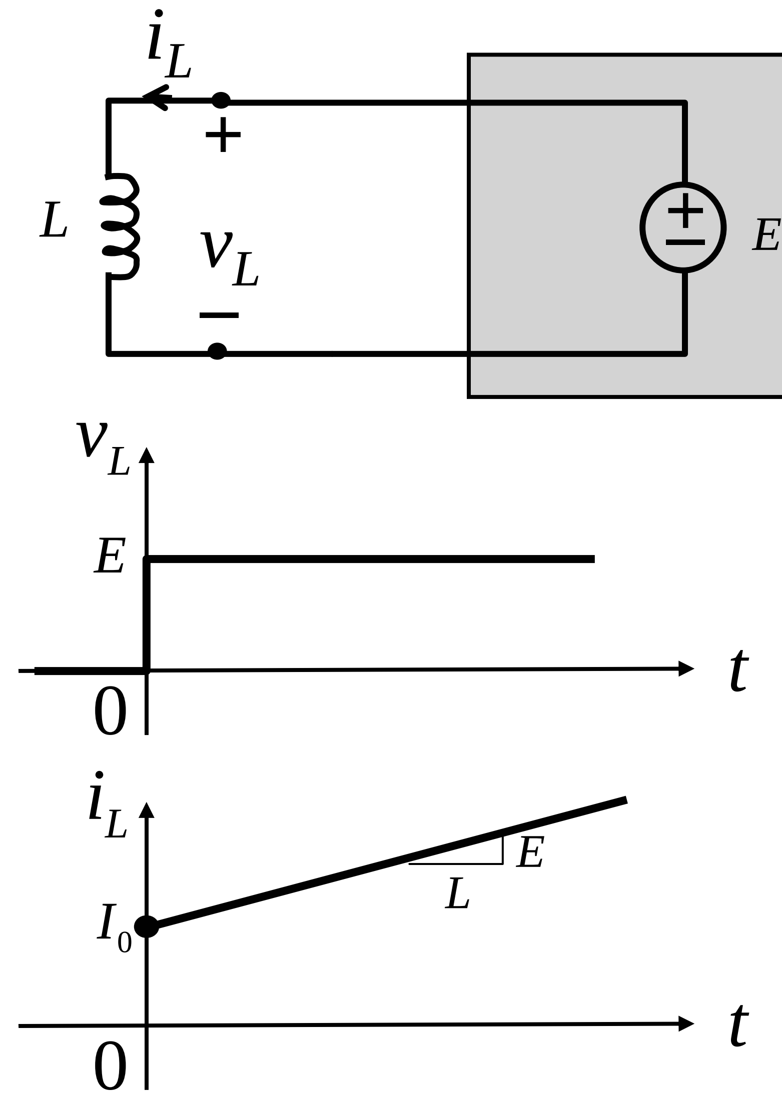
Inductor Voltage Jump Rule

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

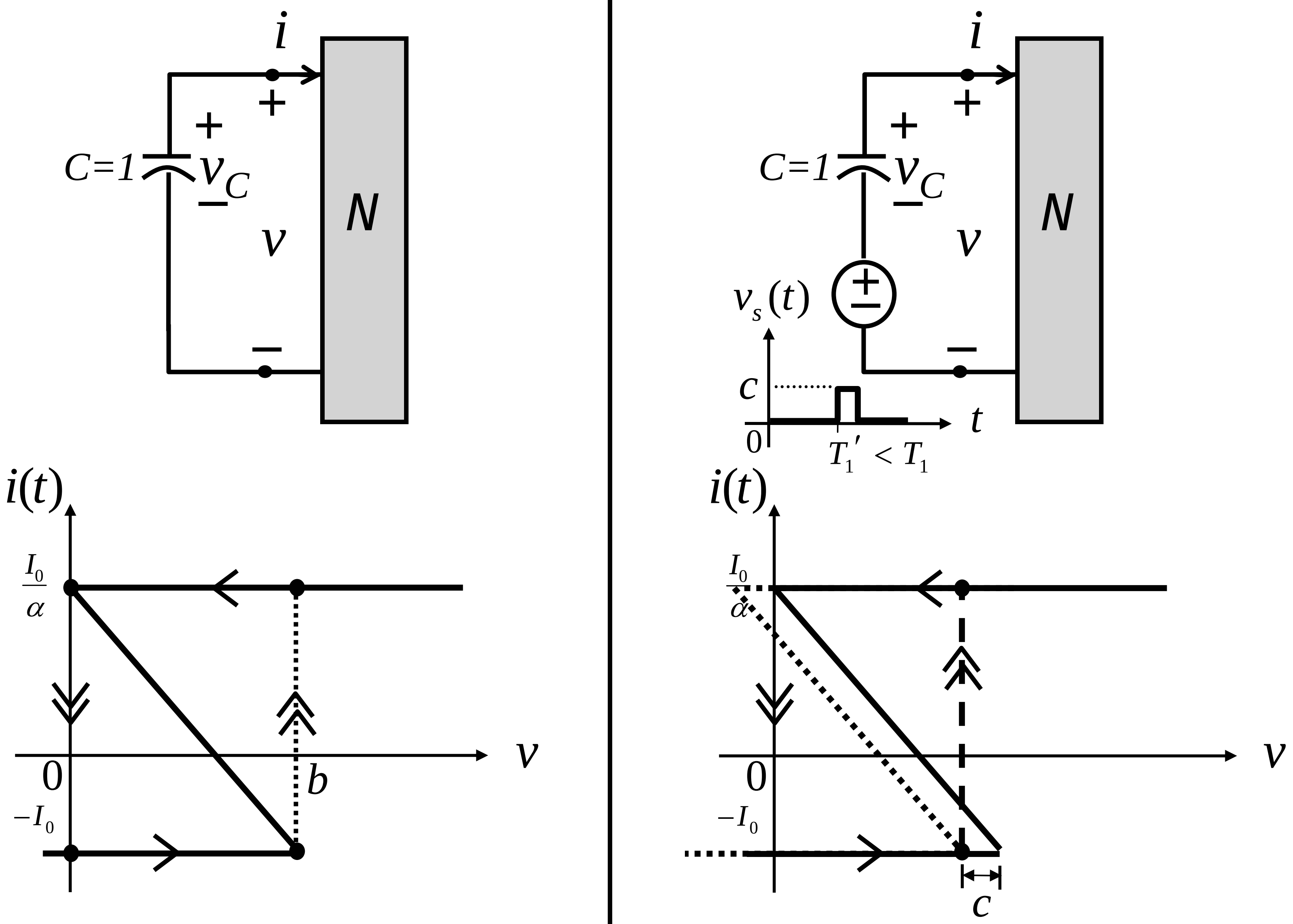
$$i_L(t_k^+) = i_L(t_k^-)$$



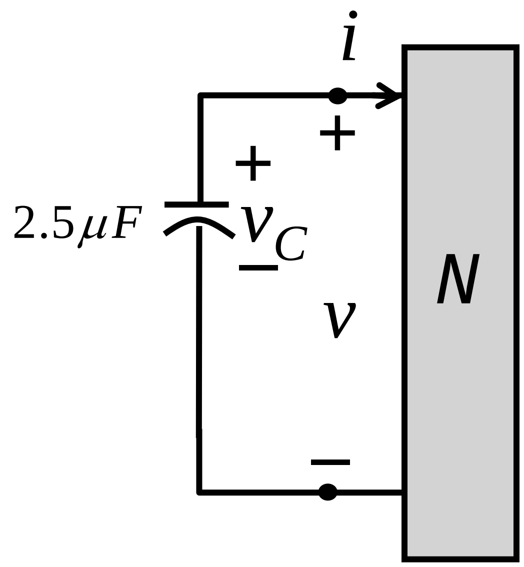
$$v_C(t) = v_C(t_0) + \int_{t_0}^{t} i_C(\tau)\, d\tau$$
$$= V_0 + \frac{I}{C} t$$



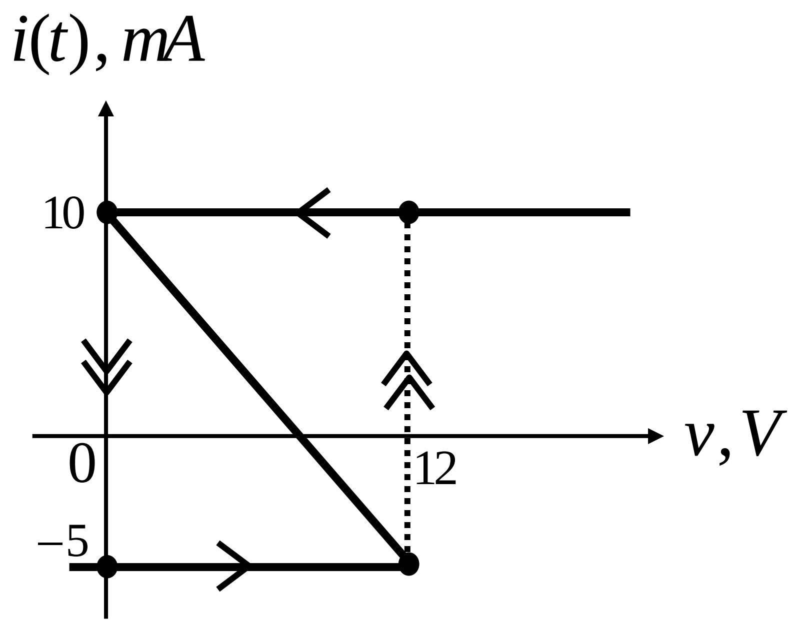
$$i_L(t) = i_L(t_0) + \int_{t_0}^{t} v_L(\tau)\, d\tau$$
$$= I_0 + \frac{E}{L} t$$



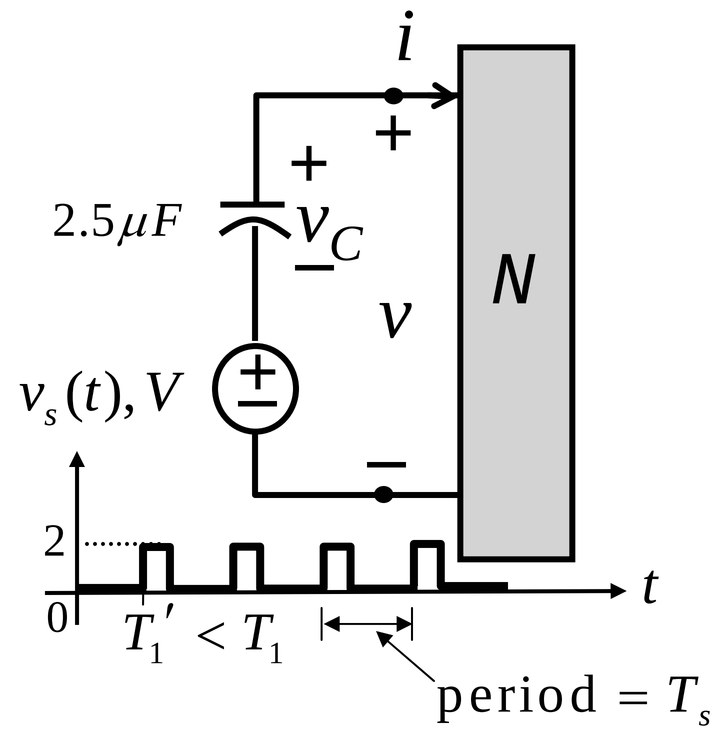
i
+
+
C=1
v
C
−
v
N
−
i(t)
I0
α
0
v
b
−I0
i
+
+
C=1
v
C
−
v
N
±
vs(t)
−
c
0
t
T1′ < T1
i(t)
I0
α
0
v
−I0
c



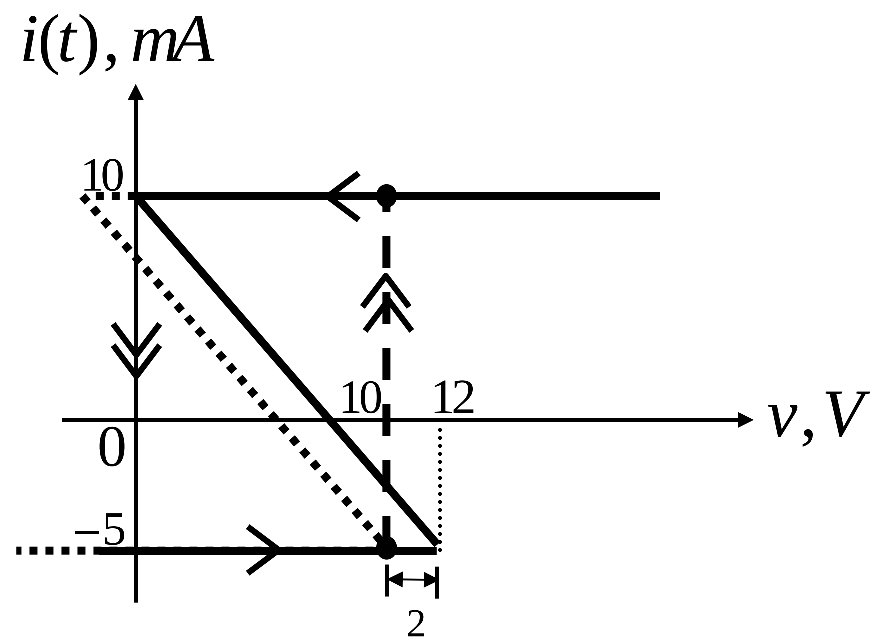
i
$+$
$+$
$2.5\mu F$
v_C
$-$
N
v
$-$



$i(t), mA$
10
0
12
-5
v, V



i
$+$
$+$
$2.5\mu F$
v_C
$-$
N
v
$v_s(t), V$
$-$
2
0
t
$T_1' < T_1$
period $= T_s$



$i(t), mA$
10
10
12
0
-5
v, V
2

Proof.

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

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

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

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

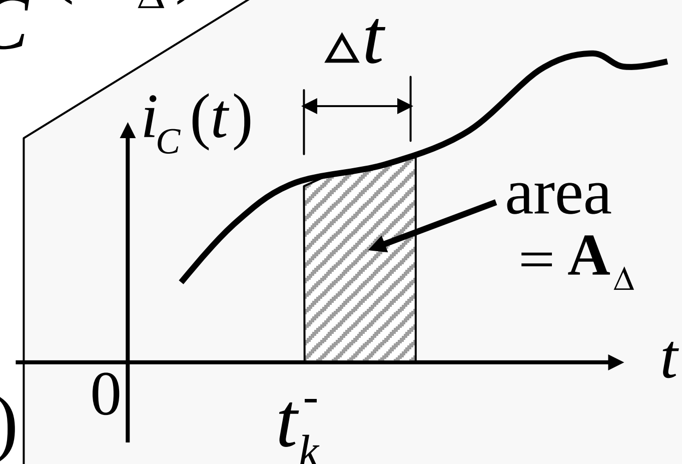
as $\triangle t \to 0$,

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

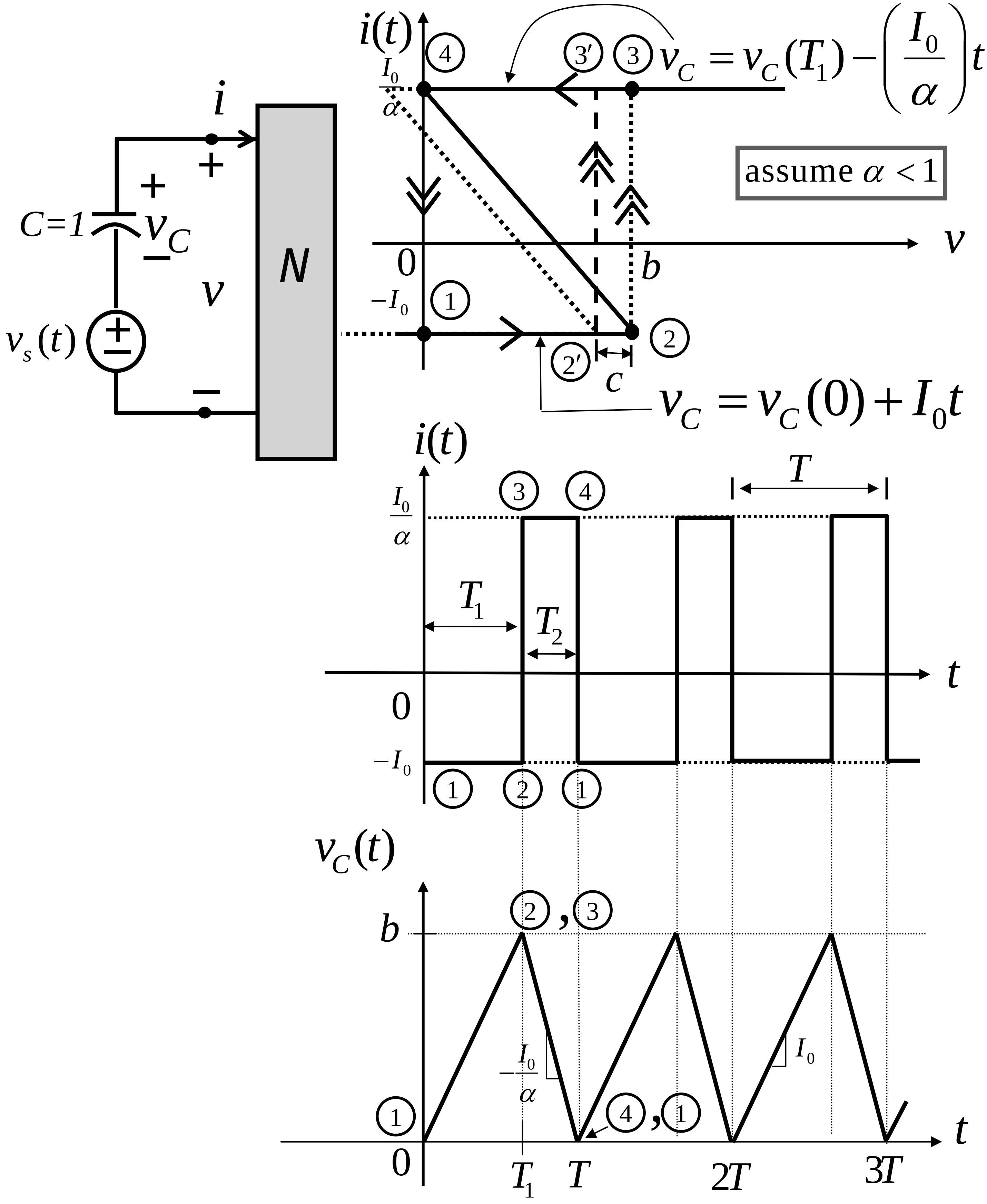
$\mathbf{A}_\Delta \to 0$

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

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



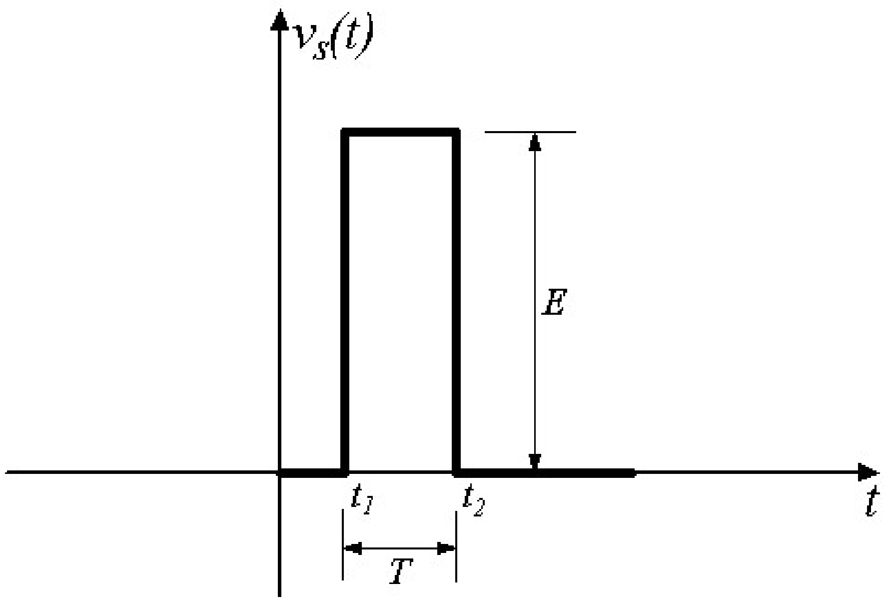
$$\int_{t_k^-}^{t_k^- + \triangle t} i_C(t)\,dt = \mathbf{A}_\Delta$$

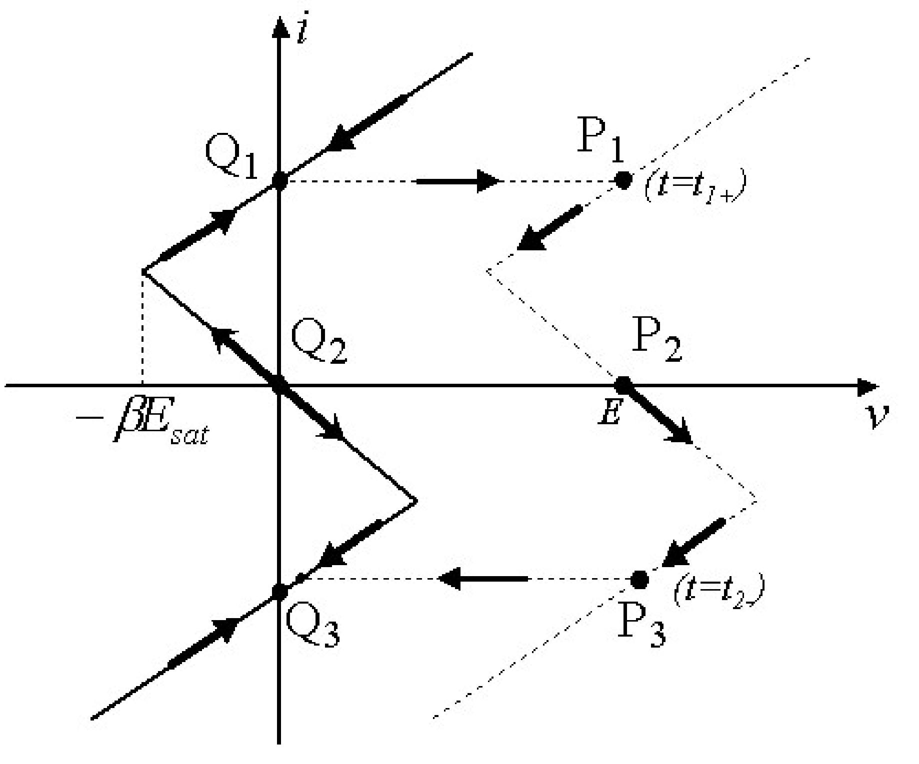


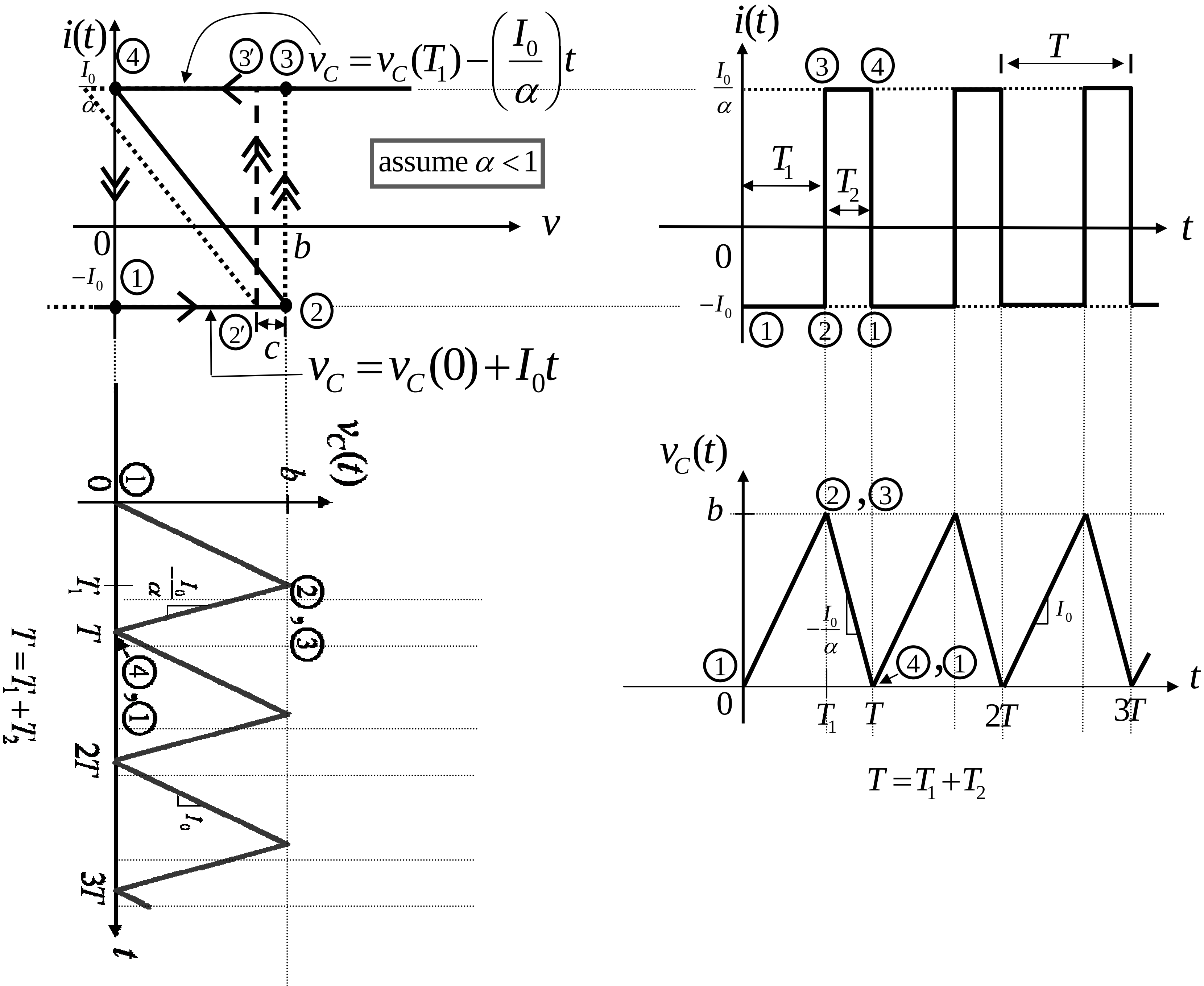
i(t)
v_C = v_C(T_1) − (I_0/α) t
assume α < 1
v
b
c
v_C = v_C(0) + I_0 t
C=1
v_C
N
v_s(t)
i(t)
T
T_1
T_2
t
v_C(t)
b
2T
3T

$$T = T_1 + T_2$$

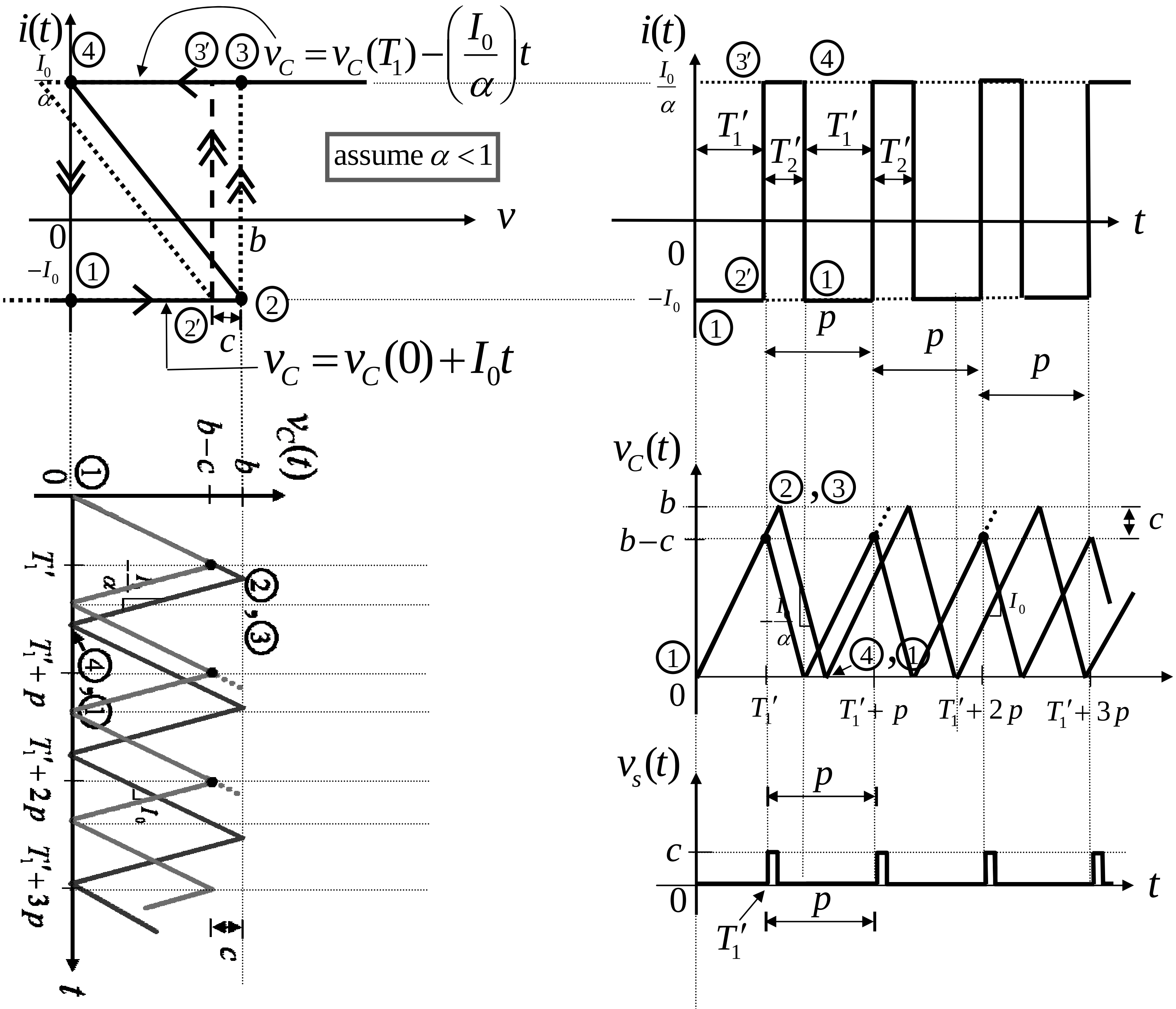
Dynamic Route of the Bi-stable op-amp Circuit Corresponding to a Square Pulse Triggering Signal







i(t)
④
③′
③
$v_C = v_C(T_1) - \left(\frac{I_0}{\alpha}\right)t$
$\frac{I_0}{\alpha}$
assume $\alpha < 1$
v
0
b
$-I_0$
①
②
②′
c
$v_C = v_C(0) + I_0 t$
$v_C(t)$
T_1
T
2T
3T
t
$-\frac{I_0}{\alpha}$
I_0
②,③
④,①
$T = T_1 + T_2$
T_2



i(t)
v
0
b
c
I0/α
−I0
1
2
2′
3
3′
4
vC = vC(T1) − (I0/α)t
vC = vC(0) + I0t
assume α < 1
t
T1′
T2′
p
vC(t)
b − c
T1′ + p
T1′ + 2p
T1′ + 3p
vs(t)