# 8-Mavzu: Ikkinchi tartibli elektr zanjiri.

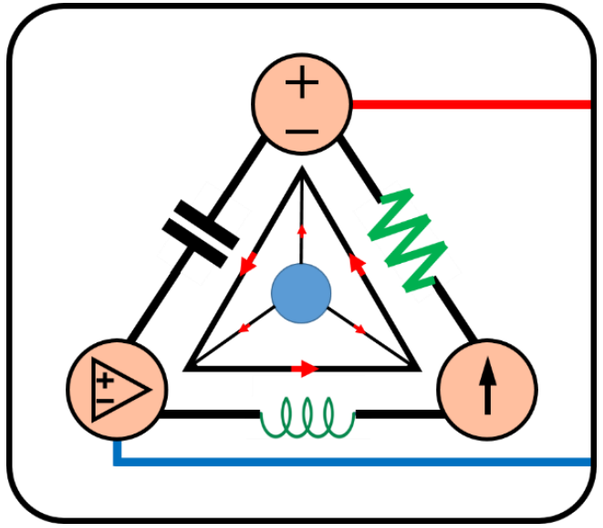
(8th Topic: Second-Order Circuit)

## 8-Mavzuning 1-qismi

*(1st part of the 8th Topic)*

***9-hafta uchun***

*For the 9th week*



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*Toshkent shahri, Usmon Nosir, 156-uy.*

# 8-Mavzu: Ikkinchi tartibli elektr zanjiri.

(8th Topic: Second-Order Circuit)

**O‘quv rejasi:**

**8.1. Umumiy tushunchalar.**

**8.2. Boshlang‘ich va yakuniy qiymatlarni topish.**

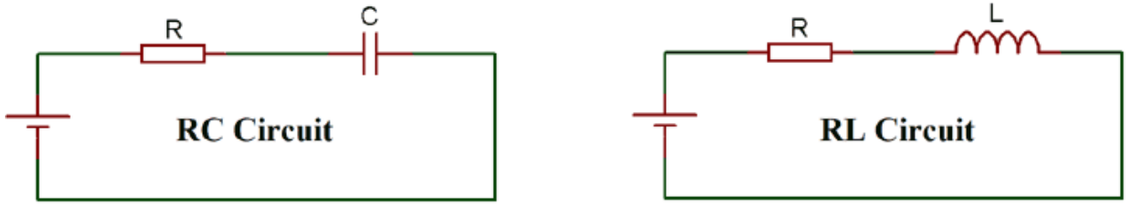
**8.3. Manbadan holi ketma-ket ulangan qarshilik, induktor va kondensator (RLC) zanjiri.**

**8.4. Manbadan holi parallel ulangan qarshilik, induktor va kondensator (RLC) zanjiri.**

# 8.1. Umumiy tushunchalar.

Bitta saqlash elementi (***kondensator*** *yoki* ***induktor***) bo‘lgan zanjirlarni tahlil qildik.

Bunday zanjirlar birinchi tartibli elektr zanjiri deb nomlangan edi. Chunki, ularni tavsiflovchi differensial tenglamalar birinchi tartibli tenglamani hosil qilgan.



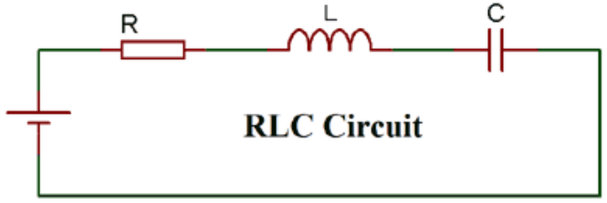




**Photo source:** [2] -https://circuitdigest.com/sites/default/files/projectimage_tut/RC-RL-and-RLC-circuits.png

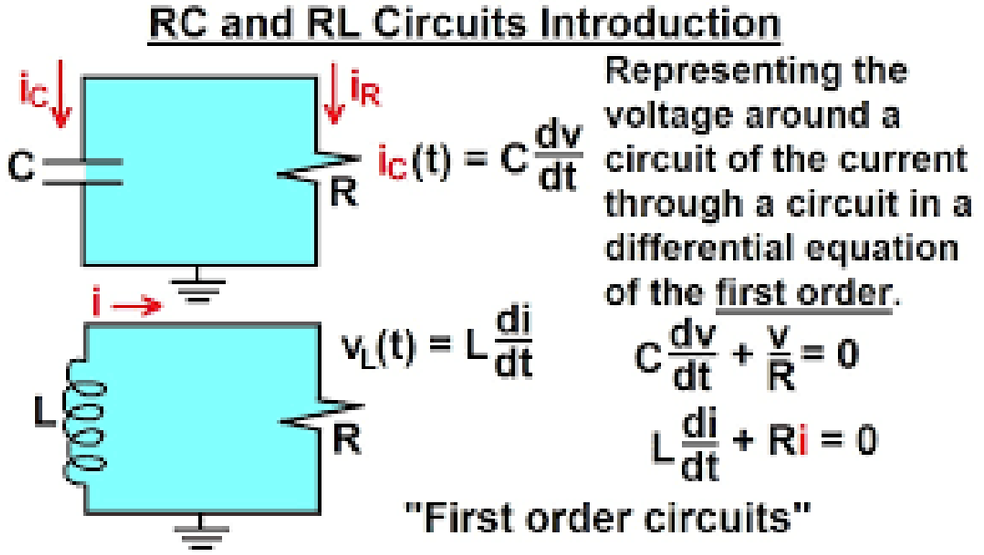
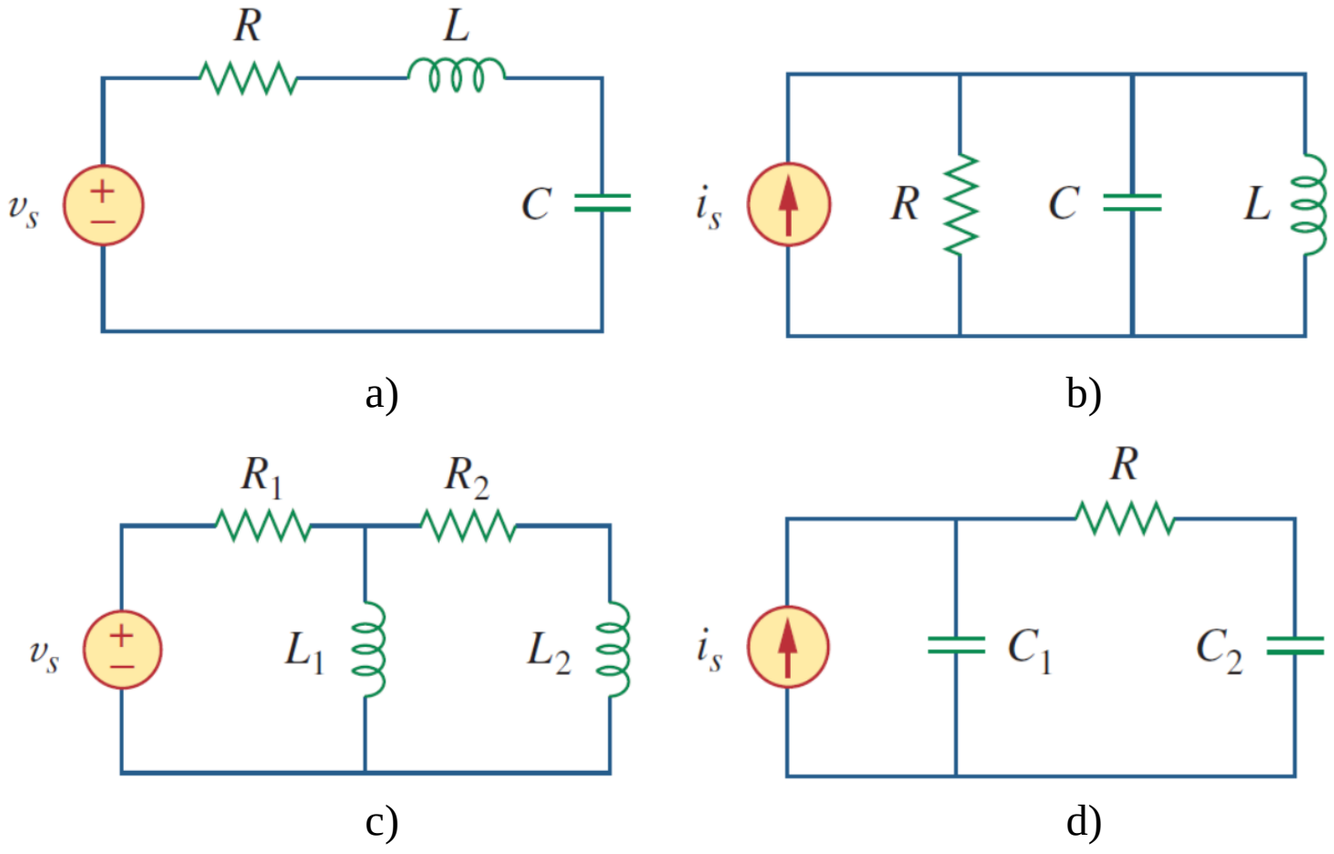



**Photo source:** [1] - https://i.ytimg.com/vi/uXuuJOdQoO4/sddefault.jpg

Ushbu mavzuda ikkita saqlash elementini o‘z ichiga olgan zanjirlarni ko‘rib chiqamiz.




**8.1-rasm. Ikkinchi tartibli zanjirning oddiy namunalari.**

a) ketma-ket ulangan *RLC* zanjiri, b) parallel ulangan *RLC* zanjiri, c) T-konfiguratsiyali *RL* zanjiri, d) Π-konfiguratsiyali *RC* zanjiri.

Ular ikkinchi tartibli zanjirlar deb nomlanadi, chunki ularning reaksiyalari ikkinchi hosilalarni o‘z ichiga olgan differensial tenglamalar bilan tavsiflanadi.

Ikkinchi tartibli zanjir har xil turdagi yoki bir xil turdagi ikkita saqlash elementiga ega bo‘lishi mumkin (*agar bir xil turdagi elementlarni ekvivalentini bitta element bilan ifodalash mumkin emas*).

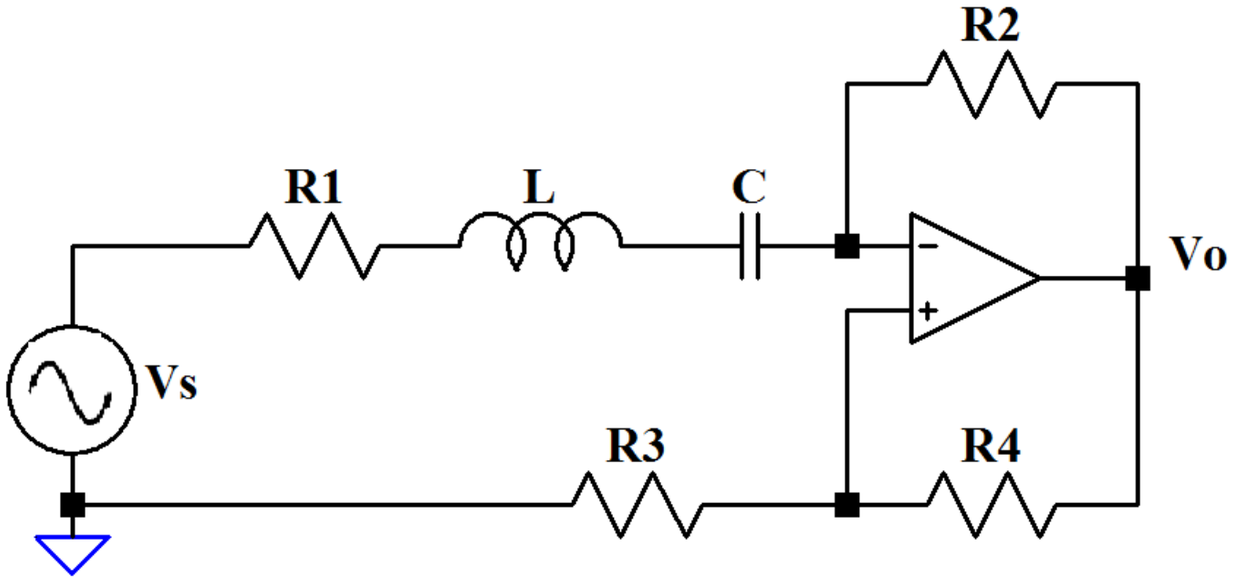



**Photo source:** [3] - https://www.researchgate.net/publication/351901076/figure/fig1/AS:1028372197040133@1622194446686/A-resonator-model-based-on-positive-feedback-concept-using-an-operational-amplifier-and.ppm

Birinchi tartibli zanjirlarda bo‘lgani kabi, ikkinchi tartibli zanjirda ham bir nechta rezistorlar, mustaqil va bog‘liq bo‘lgan manbalar bo‘lishi mumkin.

Ikkita saqlash elementi bo‘lgan operatsion kuchaytirgich zanjiri ham ikkinchi tartibli zanjir bo‘lishi mumkin.

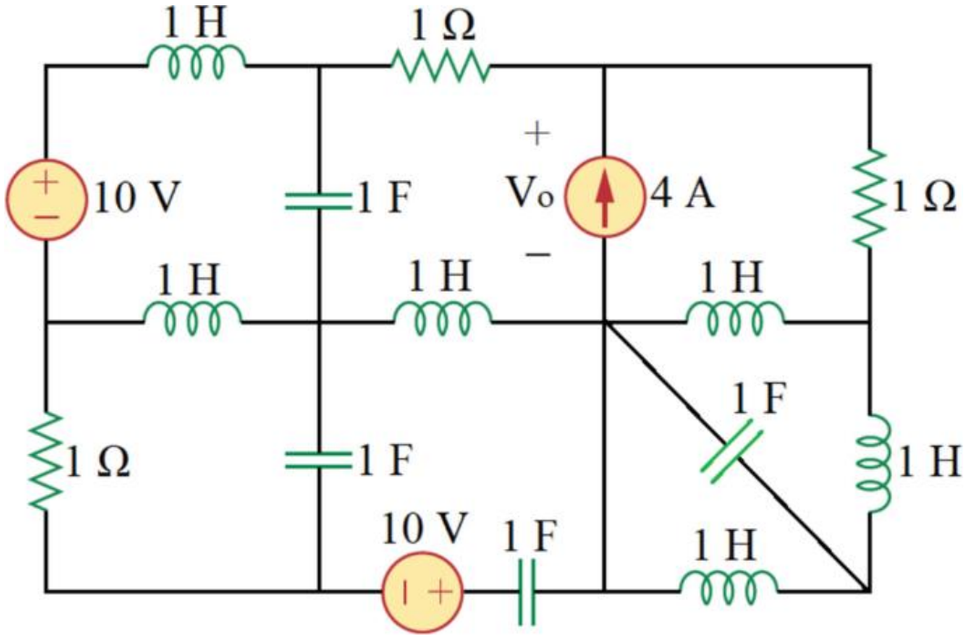



**Photo source:** [4] -https://media.springernature.com/lw685/springer-static/image/chp%3A10.1007%2F978-3-030-50711-4_5/MediaObjects/495176_1_En_5_Fig1_HTML.png

Birinchi tartibli elektr zanjirini tahlil qilishda ishlatilgan usullar ikkinchi tartibli elektr zanjirlarini tahlil qilishda ham qo‘llaniladi.

$$W_T = \frac{1}{2} L I_0^2 + \frac{1}{2} C U_0^2$$

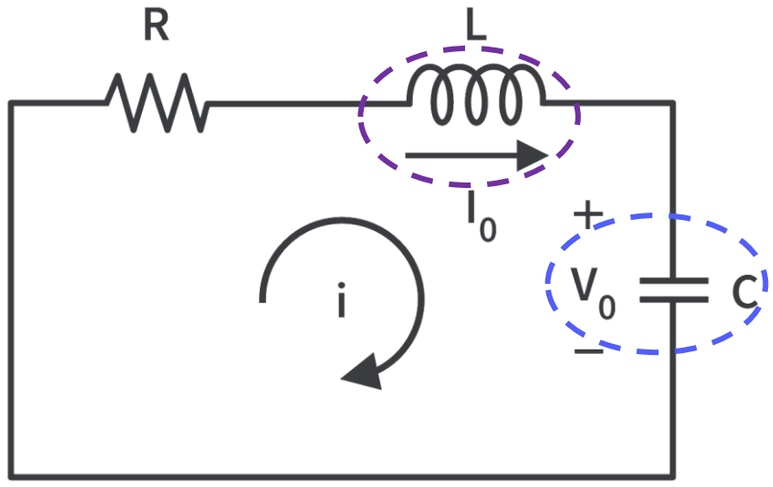



**Photo source:** [5] -https://dwma4bz18k1bd.cloudfront.net/equations/3.jpg

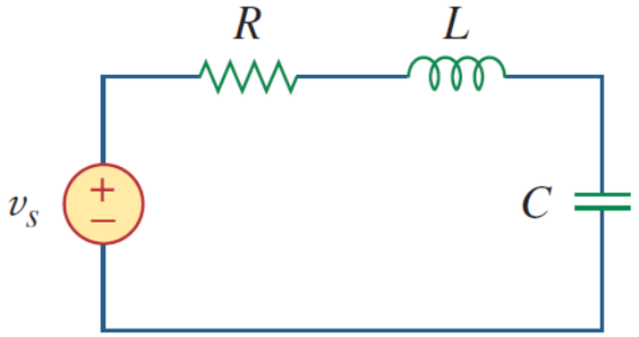
Manbadan holi ***RLC*** zanjirining yechimi zanjirning tabiiy reaksiyasi deb ataladi.

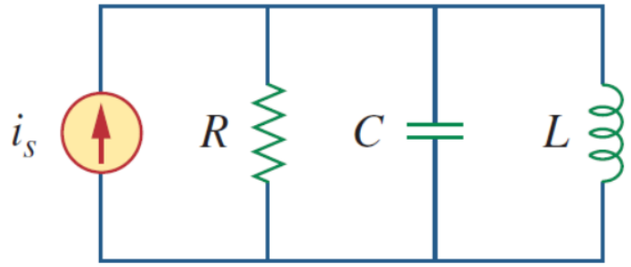
Kondensator va induktorda saqlangan dastlabki energiyalar zanjirni uyg‘otadi.

Ushbu zanjirlar vaqtinchalik reaksiyani ham, barqaror holatdagi reaksiyani ham beradi.

Biz ushbu mavzuda faqat o‘zgarmas tok (DC) mustaqil manbalarini ko‘rib chiqamiz.

Biz zanjir o‘zgaruvchilari va ularning hosilalari uchun dastlabki shartlarni qanday olishni o‘rganishdan boshlaymiz, chunki bu ikkinchi tartibli zanjirlarni tahlil qilish uchun juda muhimdir.




Ketma-ket va parallel *RLC* zanjirlarini energiyani saqlash elementlarining dastlabki shartlari va qadamli kirishlar bo‘yicha ko‘rib chiqamiz.

Keyinchalik ikkinchi tartibli elektr zanjirlarining boshqa turlarini, shu jumladan operatsion kuchaytirgich zanjirlarini ko‘rib o‘tamiz.

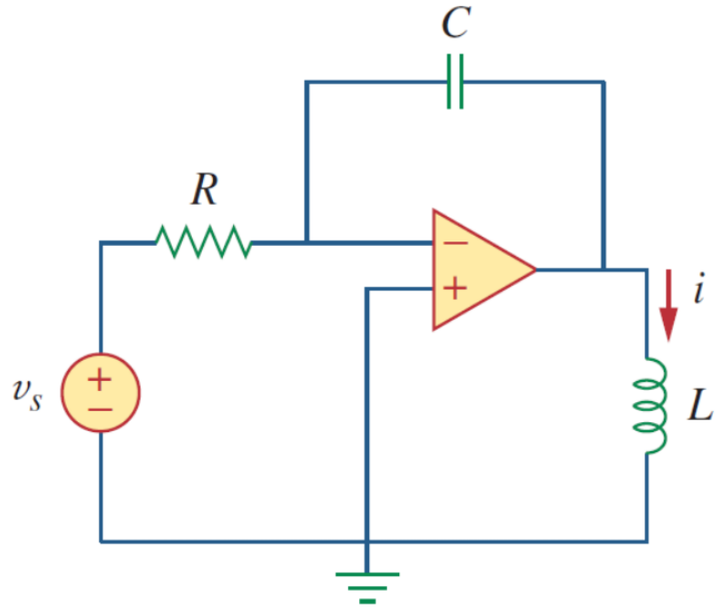



**Photo source:** [6] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 365.

# 8.2. Boshlang‘ich va yakuniy qiymatlarni topish.

Ikkinchi tartibli elektr zanjirlar bilan ishlashda duch keladigan asosiy muammo bu zanjir o‘zgaruvchilari bo‘yicha dastlabki va yakuniy shartlarni topishdir.

$u$ va $i$ ning boshlang‘ich va yakuniy qiymatlarini olishda ularning hosilalarining boshlang‘ich qiymatlarini topiladi:

$$u(t)\ va\ i(t) \qquad \frac{du(t)}{dt}\ va\ \frac{di(t)}{dt}$$

$$u(0)\ va\ i(0) \qquad \frac{du(0)}{dt}\ va\ \frac{di(0)}{dt}$$

$$u(\infty) va\ i(\infty)$$

Demak, $u$ kondensator kuchlanishini $i$ esa induktor tok kuchini bildiradi.

Dastlabki shartlarni aniqlashda ikkita asosiy fikrni yodda tutish kerak.

Birinchidan, zanjirni tahlil qilishda - biz kondensator bo‘ylab kuchlanishning $u(t)$ qutblanishini va induktor orqali tok kuchi $i(t)$ yo‘nalishini ehtiyotkorlik bilan ko‘rib chiqishimiz kerak.

Demak, $u$ va $i$ qat’iy ravishda passiv belgi konvensiyasiga muvofiq belgilanadi. Ular qanday ta’riflanganligini diqqat bilan kuzatish va shunga mos ravishda qo‘llash kerak.

Ikkinchidan, shuni yodda tutish kerakki, kondensator kuchlanishi doimo o‘zgarmas bo‘ladi.

$$u(0^+) = u(0^-) \qquad (8.1a)$$

Shuningdek, induktorning tok kuchi ham doimo o‘zgarmas bo‘ladi.

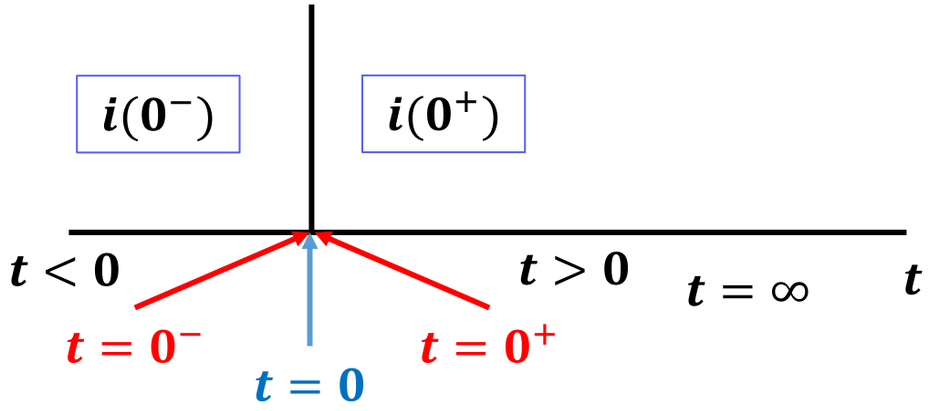
$$i(0^+) = i(0^-) \qquad (8.1b)$$

bu yerda:

$t = 0^-$ almashtirishdan oldingi vaqtni bildiradi;

$t = 0^+$ almashtirishdan keyingi vaqtni bildiradi;

$t = 0$ da almashish sodir bo‘ladi deb faraz qilinadi.

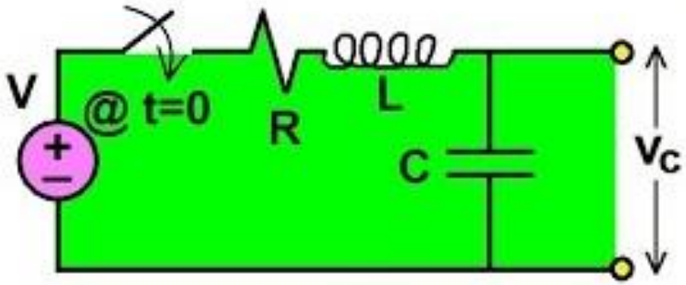



Demak, dastlabki shartlarni topishda birinchi navbatda (8.1) tenglamani qo‘llash orqali keskin o‘zgarmaydigan o‘zgaruvchilarga, kondensator kuchlanishiga va induktor tok kuchiga e’tibor qaratiladi.

# Ikkinchi tartibli elektr zanjirini tahlil qilishning startegiyasi.

## The Key to Solving Second Order Circuits

"Find the initial and final values of:"




1) $i(t=0^-)$ $v(t=0^-)$

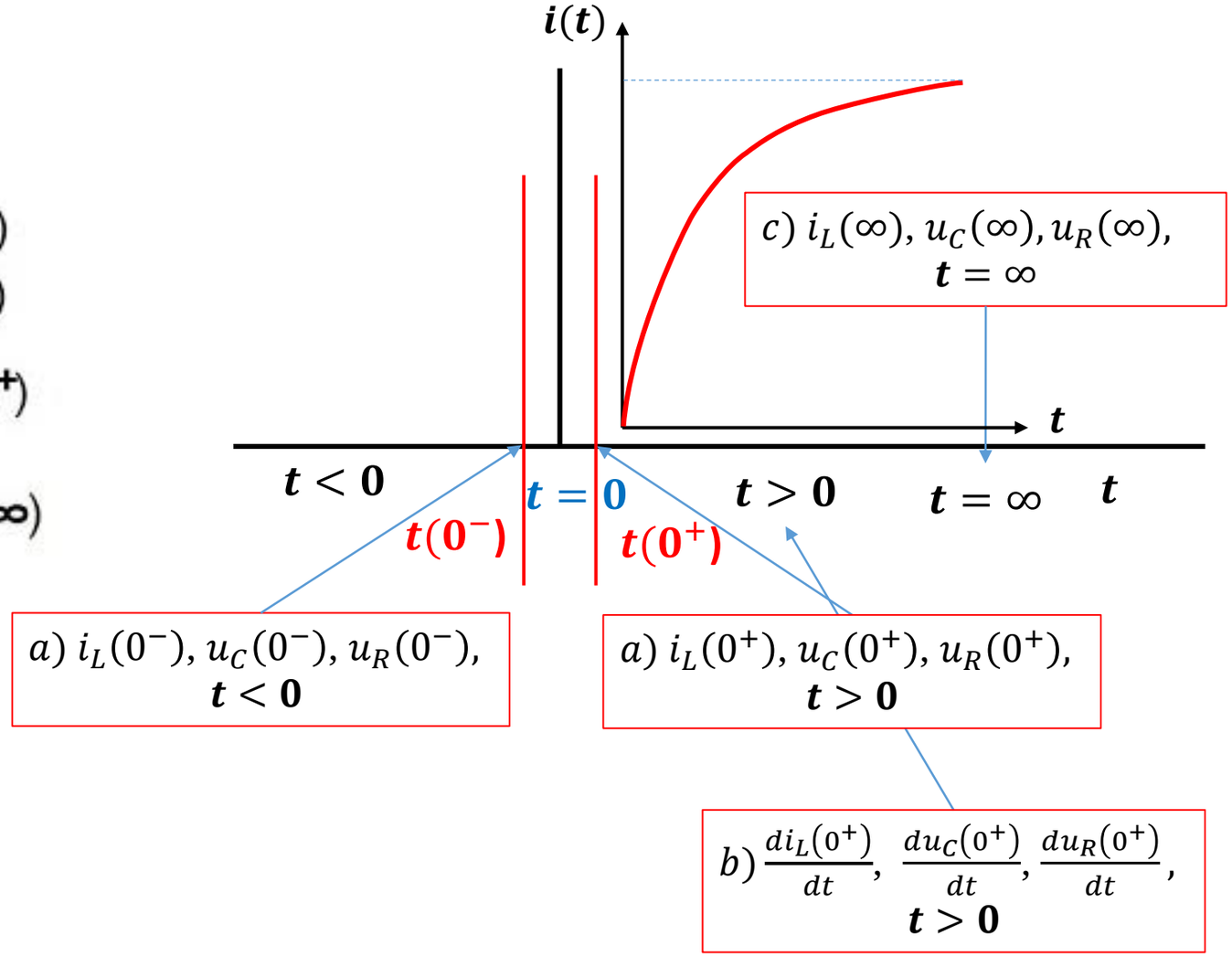
2) $i(t=0^+)$ $v(t=0^+)$

3) $\frac{di}{dt}(t=0^+)$ $\frac{dv}{dt}(t=0^+)$

4) $i_L(t\to\infty)$ $v_C(t\to\infty)$

$$\frac{di_L}{dt}=\frac{v_L}{L} \qquad \frac{dv_C}{dt}=\frac{i_C}{C}$$

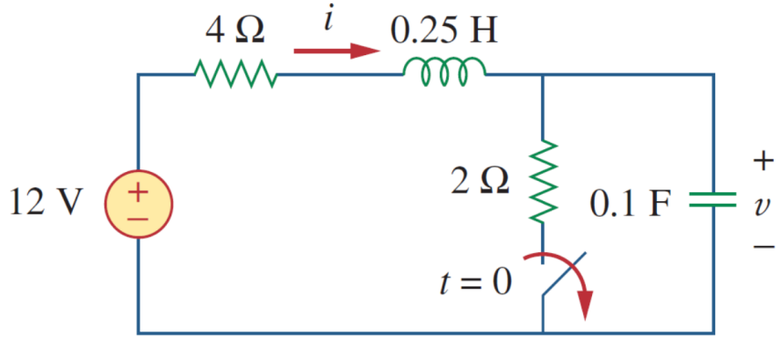
**Photo source:** [7] -https://i.ytimg.com/vi/B79Kye6U_vw/hqdefault.jpg



***8.2.1-masala:*** 8.2-rasmdagi kalit uzoq vaqt davomida yopilgan. U $t = 0$ da ochiladi.

Quyidagi: a) $i(0^+), u(0^+)$, b) $di(0^+)/dt,\ du(0^+)/dt$, c) $i(\infty), u(\infty)$ larni toping.

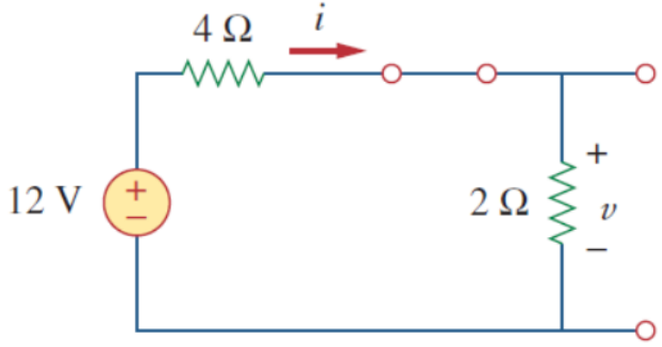



**8.2-rasm.**

***Yechish:***

a) $t = 0^-$ uchun

$$i(0^-) = \frac{12}{4+2} = 2\ A, \qquad u(0^-) = 2i(0^-) = 4\ V$$



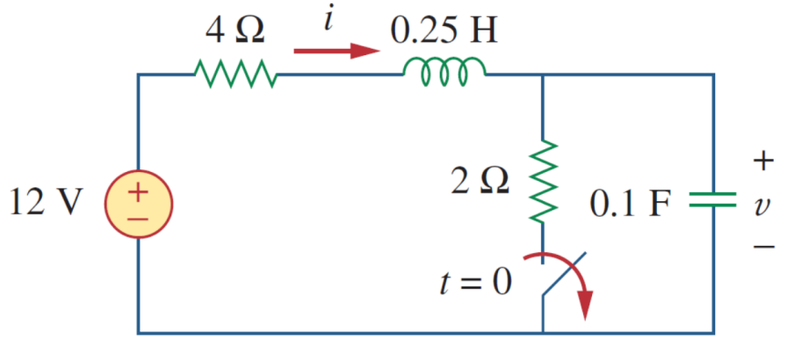

a)

**8.3-rasm. 8.2-rasmni ekvivalent zanjiri:**
a) $t = 0^-$ uchun,

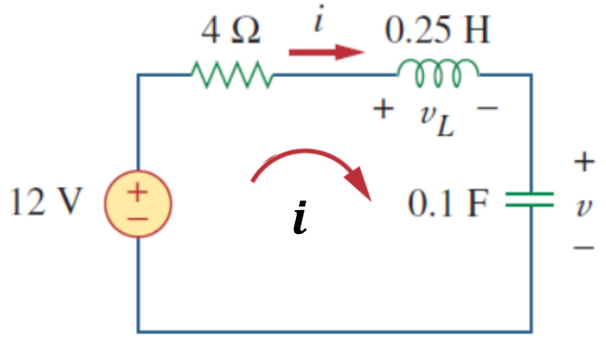
$$i(0^+) = i(0^-) = 2\ A \qquad u(0^+) = u(0^-) = 4\ V$$

***8.2.1-masala:*** 8.2-rasmdagi kalit uzoq vaqt davomida yopilgan. U $t = 0$ da ochiladi.

Quyidagi: a) $i(0^+), u(0^+)$, b) $di(0^+)/dt,\ du(0^+)/dt$, c) $i(\infty), u(\infty)$ larni toping.




**8.2-rasm.**




b)

**8.3-rasm. 8.2-rasmni ekvivalent zanjiri:**
b) $t = 0^+$ uchun

***Yechish:*** b) $t = 0^+$ uchun $\quad i_c(0^+) = i(0^-) = 2\ A$

Kondensator uchun $C\frac{du}{dt} = i_c \rightarrow \quad \frac{du}{dt} = \frac{i_c}{C}$

Induktor uchun $L\frac{di}{dt} = u_L \downarrow$

$$\frac{du(0^+)}{dt} = \frac{i_c(0^+)}{C} = \frac{2}{0{,}1} = 20\frac{V}{s}$$

$$\frac{di}{dt} = \frac{u_L}{L}$$

$\boldsymbol{u_L}$ =?

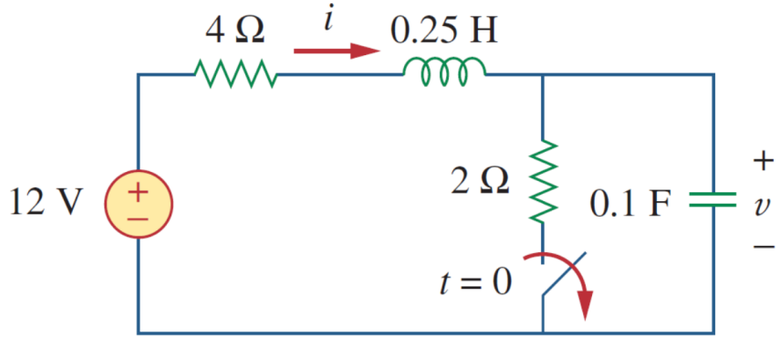
KVL qo‘llaymiz: $\quad -12 + 4i(0^+) + u_L(0^+) + u(0^+) = 0$

$$u_L(0^+) = 12 - 8 - 4 = 0$$

$$\frac{di(0^+)}{dt} = \frac{u_L(0^+)}{L} = \frac{0}{0{,}25} = 0\frac{A}{s}$$

***8.2.1-masala:*** 8.2-rasmdagi kalit uzoq vaqt davomida yopilgan. U $t = 0$ da ochiladi.

Quyidagi: a) $i(0^+), u(0^+)$, b) $di(0^+)/dt,\ du(0^+)/dt$, c) $i(\infty), u(\infty)$ larni toping.




**8.2-rasm.**

***Yechish:***

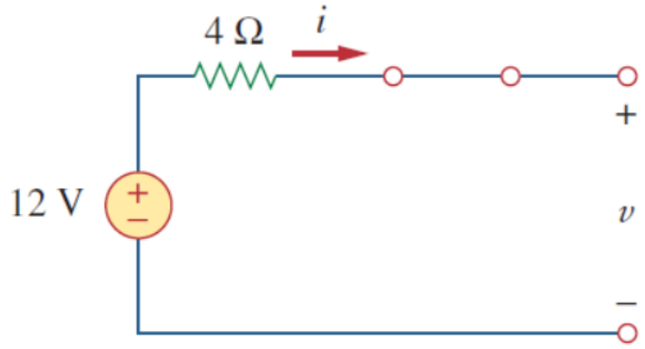
c) $t > 0$ uchun zanjir vaqtinchalikka uchraydi.

$t \to \infty$ da zanjir yana barqaror holatga erishadi.

Induktor berk zanjir va kondensator ochiq zanjir kabi ishlaydi.

$$i(\infty) = 0\ A$$

$$u(\infty) = 12\ V$$

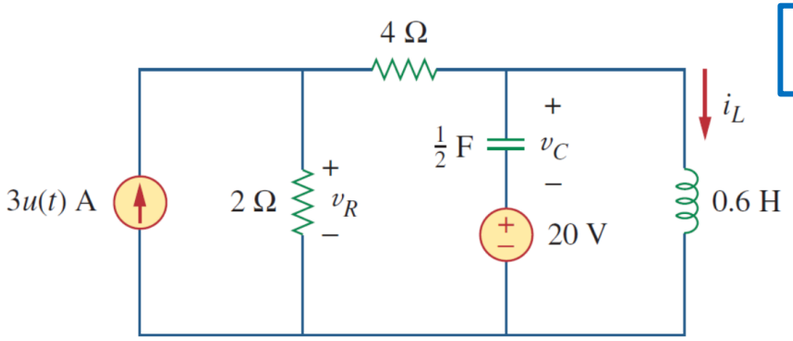



c)

**8.3-rasm. 8.2-rasmni ekvivalent zanjiri:**
c) $t \to \infty$ uchun.

***8.2.2-masala:*** 8.4-rasmdagi kalit uzoq vaqt davomida yopilgan. U $t = 0$ da ochiladi.

Quyidagi: a) $i_L(0^+)$, $u_C(0^+)$, $u_R(0^+)$; b) $\frac{di_L(0^+)}{dt}$, $\frac{du_C(0^+)}{dt}$, $\frac{du_R(0^+)}{dt}$; c) $i_L(\infty)$, $u_C(\infty)$ *va* $u_R(\infty)$larni toping.

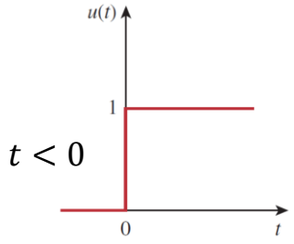



**8.4-rasm.**

***Yechish:***

a) $t < 0$ uchun

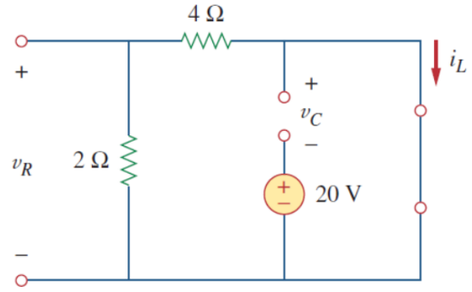
$3u(t) = 0$



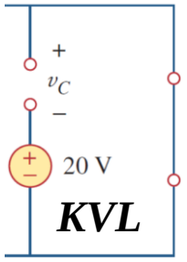

$i_L(0^-) = 0$ A

$u_R(0^-) = 0$ V

$u_C(0^-) = -20\ V$



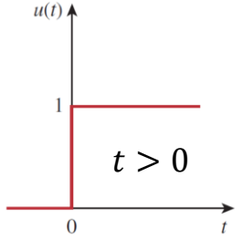

a) $t = 0^-$ uchun




$-20 - u_C(0^-) = 0$

$t > 0$ uchun

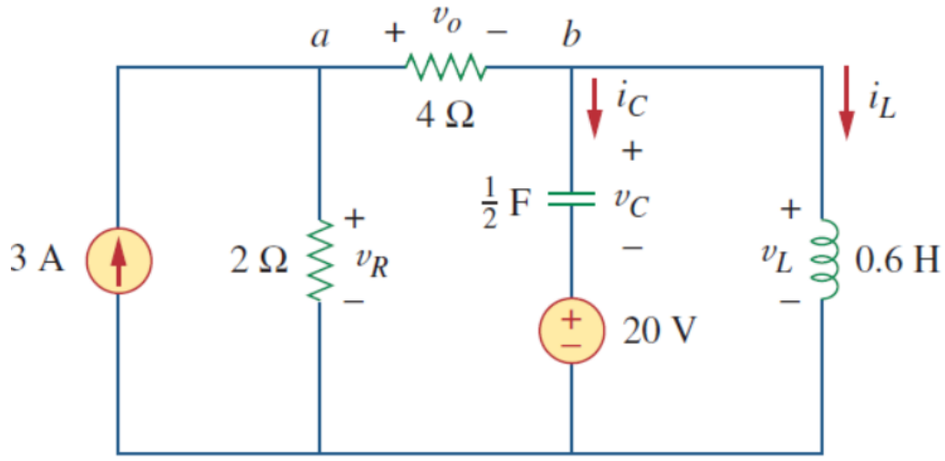
$3u(t) = 3$




$i_L(0^-) = i_L(0^+) = 0\ A$

$u_C(0^-) = u_C(0^+) = -20$ V

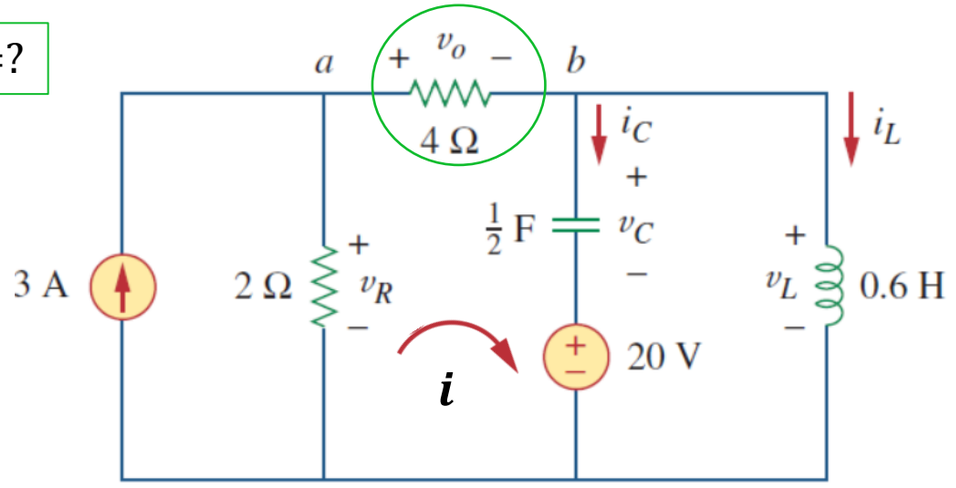
$u_R(0^+) =?$




b) $t = 0^+$ uchun

$u_R(0^+) = ?$




b) $t = 0^+$ uchun

***KCL: a tugun uchun***

$$3 = \frac{u_a}{2} + \frac{u_a - u_b}{4} \rightarrow \qquad 3 = \frac{u_R(0^+)}{2} + \frac{u_0(0^+)}{4} \rightarrow$$

$$\rightarrow 3 = \frac{u_R(0^+)}{2} + \frac{u_R(0^+)}{4}$$

$$\rightarrow 36 = 6u_R(0^+) + 3u_R(0^+)$$

$$\rightarrow 36 = 9u_R(0^+)$$

$$\rightarrow u_R\,(0^+) = 4\ \text{V}$$

$$\rightarrow u_0\,(0^+) = 4\ \text{V}$$

***KVL: mesh-2 uchun***

$$-u_R(0^+) + u_0(0^+) + u_C(0^+) + 20 = 0$$

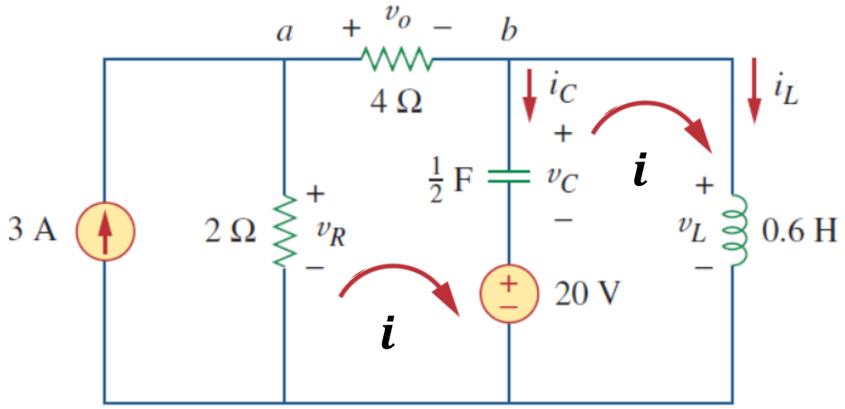
$$u_C(0^+) = -20\ \text{V}$$

$$-u_R(0^+) + u_0(0^+) - 20 + 20 = 0$$

$$-u_R(0^+) + u_0(0^+) = 0$$

$$u_R(0^+) = u_0(0^+)$$

a) $i_L(0^+) = 0\ A$ $u_C(0^+) = -20\ \text{V}$ $u_R(0^+) = 4\ \text{V}$ $u_0(0^+) = 4\ \text{V}$ b) $\frac{di_L(0^+)}{dt}$, $\frac{du_C(0^+)}{dt}$, $\frac{du_R(0^+)}{dt}$;




b) $t = 0^+$ uchun

$\frac{du_C(0^+)}{dt} = ?$ $C\frac{du_C}{dt} = i_C;$ $\frac{du_C(0^+)}{dt} = \frac{i_C(0^+)}{C};$

***KCL: b tugun uchun***

$$\frac{u_a - u_b}{4} = i_C(0^+) + i_L(0^+)$$

$$\frac{u_0(0^+)}{4} = i_C(0^+) + i_L(0^+)$$

$$\frac{4}{4} = i_C(0^+) + 0 \rightarrow \quad i_C(0^+) = 1$$

$$\frac{du_C(0^+)}{dt} = \frac{1}{0{,}5} = 2\frac{V}{s}$$

***KVL: mesh-2 uchun***

$-u_R + u_C + 20 + u_0 = 0$

Har ikki tomonni hosilasini olamiz va $t = 0^+$ni qo‘yamiz

$$-\frac{du_R(0^+)}{dt} + \frac{du_C(0^+)}{dt} + \frac{du_0(0^+)}{dt} = 0$$

$$\frac{du_R(0^+)}{dt} = 2 + \frac{du_0(0^+)}{dt} \rightarrow$$

$$\rightarrow \frac{du_R(0^+)}{dt} = 2 - 2\frac{du_R(0^+)}{dt}$$

$$3\frac{du_R(0^+)}{dt} = 2 \rightarrow \quad \frac{du_R(0^+)}{dt} = \frac{2}{3}\frac{V}{s}$$

$\frac{di_L(0^+)}{dt} = ?$ $L\frac{di_L}{dt} = u_L;$ $\frac{di_L(0^+)}{dt} = \frac{u_L(0^+)}{L};$

***KVL: mesh-3 uchun***

$$-20 - u_C(0^+) + u_L(0^+) = 0$$

$$u_L(0^+) = u_C(0^+) + 20$$

$$= -20 + 20$$

$u_L(0^+) = 0$

$$\frac{di_L(0^+)}{dt} = \frac{0}{0{,}6} = 0\frac{A}{s}$$

$\frac{du_R(0^+)}{dt} = ?$

***KCL: a tugun uchun***

$3 = \frac{u_R}{2} + \frac{u_0}{4};$

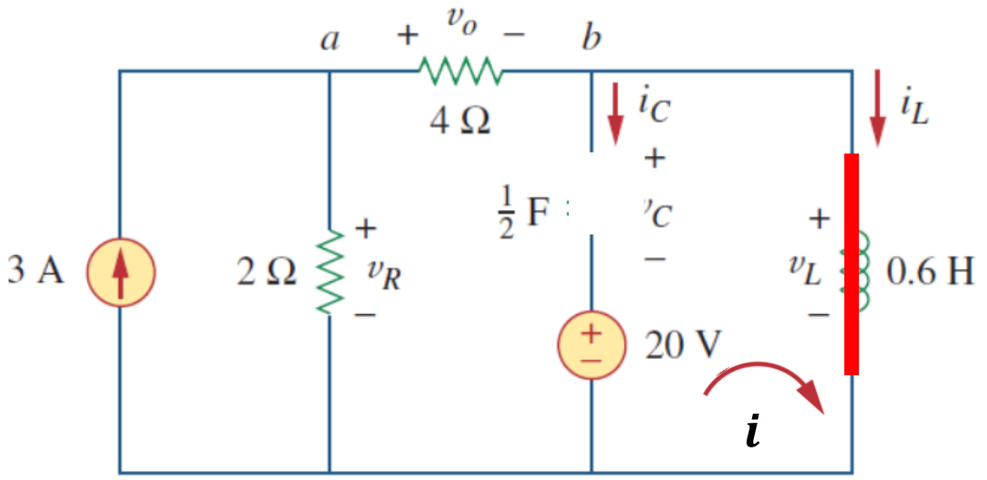
Har ikki tomonni hosilasini olamiz va $t = 0^+$ni qo‘yamiz

$12 = 2u_R + u_0;$

$$0 = 2\frac{du_R(0^+)}{dt} + \frac{du_0(0^+)}{dt}$$

$$\rightarrow \frac{du_0(0^+)}{dt} = -2\frac{du_R(0^+)}{dt}$$

c) $i_L(\infty)$, $u_C(\infty)$ $va$ $u_R(\infty)$




b) $t = 0^+$ uchun

$$u_R(\infty) = i_R(\infty) \cdot R$$

$$i_R(\infty) = \frac{3}{2+4} \cdot 4 = 2\ A$$

$$u_R(\infty) = i_R(\infty) \cdot 2 = 4\ \text{V}$$

c) $t \to \infty$, holatida zanjir barqaror holatga erishadi.

Tok kuchini bo‘linish qoidasi bo‘yicha:

$$i_L(\infty) = \frac{2}{2+4} \cdot 3 = 1\ A$$

***KVL: mesh-3 uchun***

$$-20 + u_C(\infty) = 0$$

$$u_C(\infty) = -20\ \text{V}$$

# *FOYDALANILGAN MANBALAR:*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# *E'TIBORINGIZ UCHUN RAHMAT!!!*