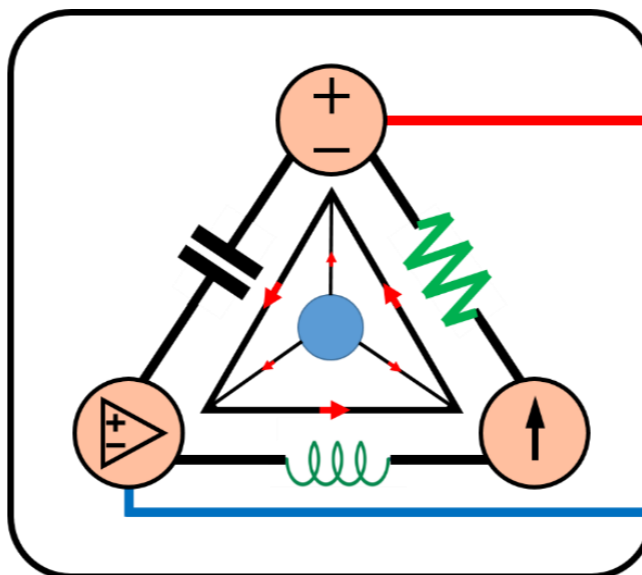


7-Mavzu: Birinchi tartibli elektr zanjiri (*davomi*).
(7th Topic: First-Order Circuit)

7-Mavzuning 4-qismi
(4th part of the 7th Topic)

8-hafta uchun
For the 8th week



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Toshkent shahri, Usmon Nosir, 156-uy.

7-Mavzu: Birinchi tartibli elektr zanjiri (*davomi*).

(7th Topic: First-Order Circuit)

O'quv rejası:

7.5. RC zanjirining qadamli reaksiyasi.

7.6. RL zanjirining qadamli reaksiyasi.

7.7. Birinchi tartibli operatsion kuchaytirgich zanjirlari.

7.8. Qo'llanilishi.

7.7. Birinchi tartibli operatsion kuchaytirgich zanjirlari.

Saqlash elementini o‘z ichiga olgan operatsion kuchaytirgich zanjiri birinchi tartibli elektr zanjirlarini hosil qiladi.

Differensiallar va integratorlar birinchi tartibli operatsion kuchaytirgich zanjirlariga misol bo‘la oladi.

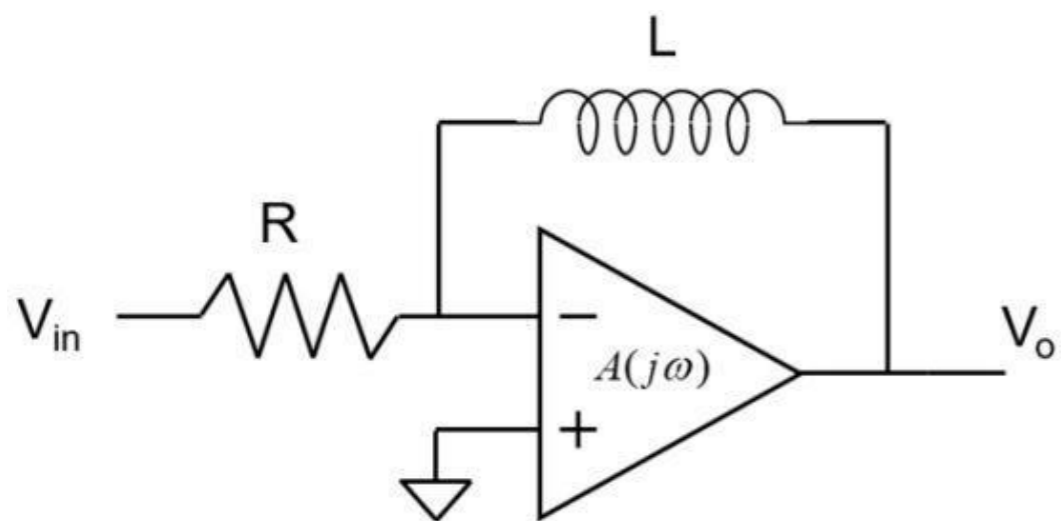


Photo source: [16] - <https://media.cheggcdn.com/media/c49/c495773b-5c61-4a1d-84f6-afea651859d5/php9Rsuc1>

Differentiator Op-amp

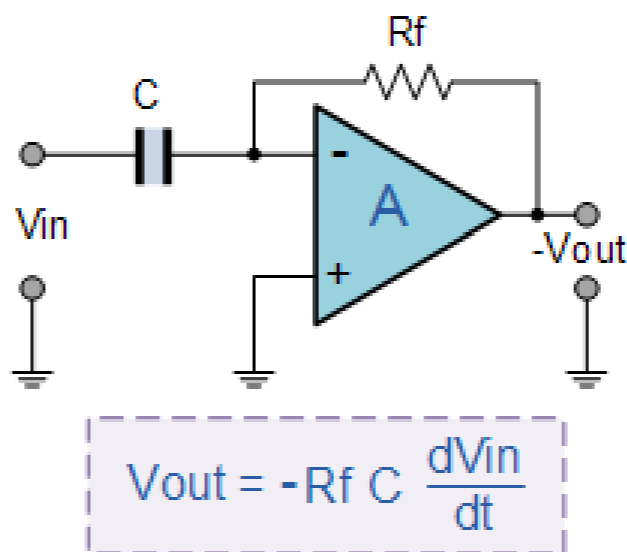
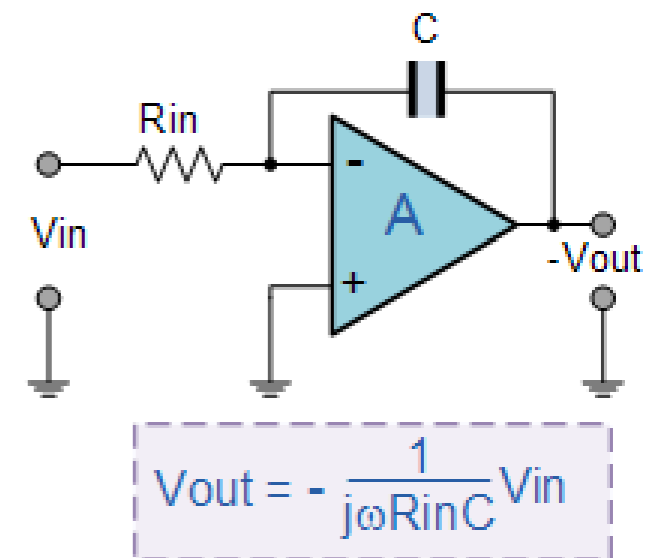


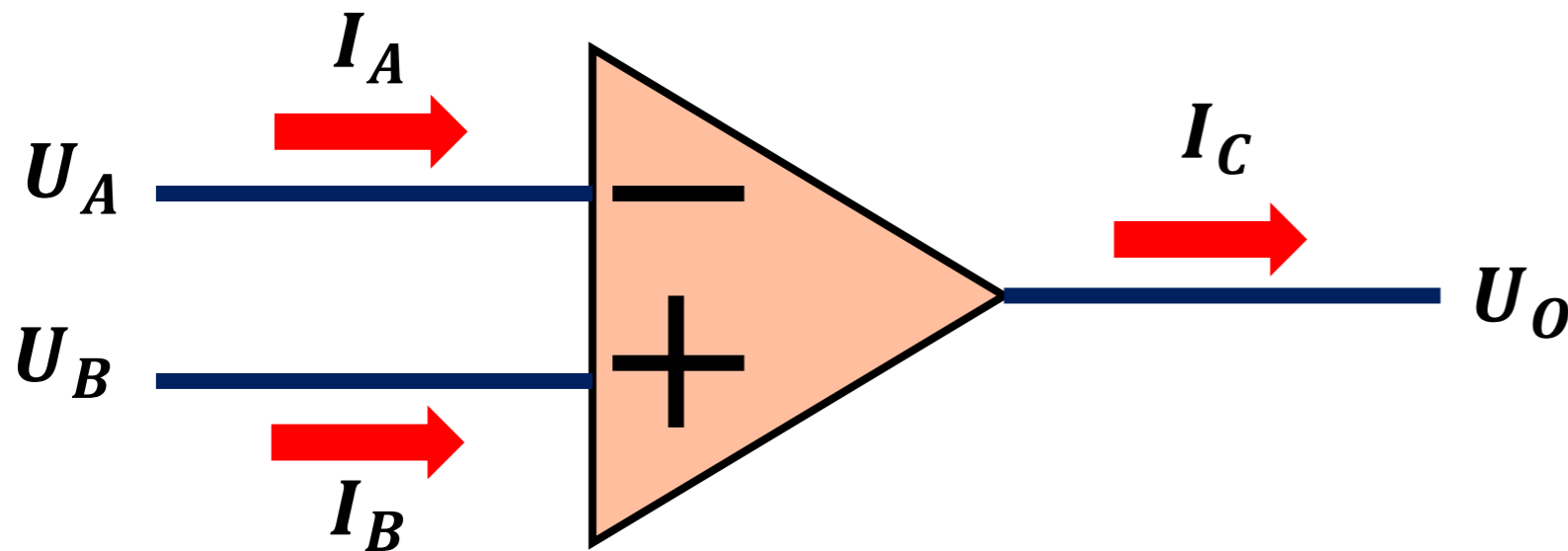
Photo source: [17] - <https://www.electronics-tutorials.ws/wp-content/uploads/2018/05/opamp-opamp51.gif>

Integrator Op-amp



Shuningdek, ba'zi sabablarga ko'ra, induktorlar operatsion kuchaytirgich zanjirlarida deyarli qo'llanilmaydi.

Shuning uchun biz bu yerda **RC** turidagi operatsion kuchaytirgich zanjirilarini ko'rib chiqamiz.



Odatdagidek, biz tugun tahlili yordamida operatsion kuchaytirgich zanjirlarini tahlil qilamiz.

1) $U_A = U_B, V$

3) $I_A + I_B \neq I_C, A$

2) $I_A = I_B = 0, A$

4) **KCL**

Quyidagi uchta misol ko'rsatiladi.

Birinchisi, *manbasiz* operatsion kuchaytirgich zanjiri bilan bog'liq,

Qolgan ikkitasi esa *qadamli reaksiyalarni* o'z ichiga oladi.

Uchta misol, kondensatorning operatsion kuchaytirgichga nisbatan joylashishiga qarab, barcha mumkin bo'lgan *RC* turlarini qamrab olish uchun ehtiyotkorlik bilan tanlangan.

Tevenin ekvivalent zanjirini hosil qilish bilan operatsion kuchaytirgich zanjirini qulay boshqarish mumkin bo'lgan zanjirga qisqartirish imkonini beradi.

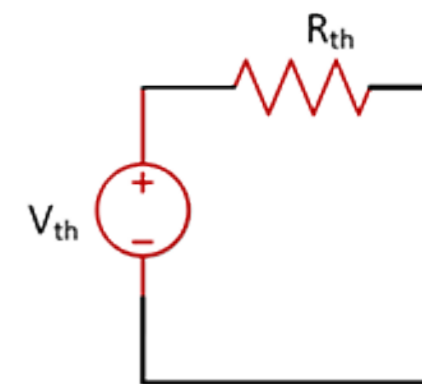
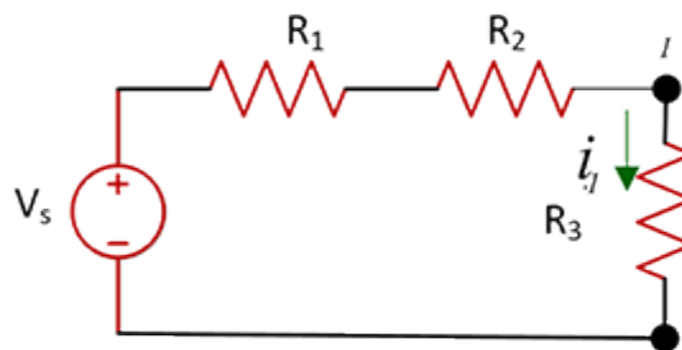


Photo source: [18] - https://www.cpp.edu/~elab/projects/project_08/images/Thevenin-1.gif

Kirish

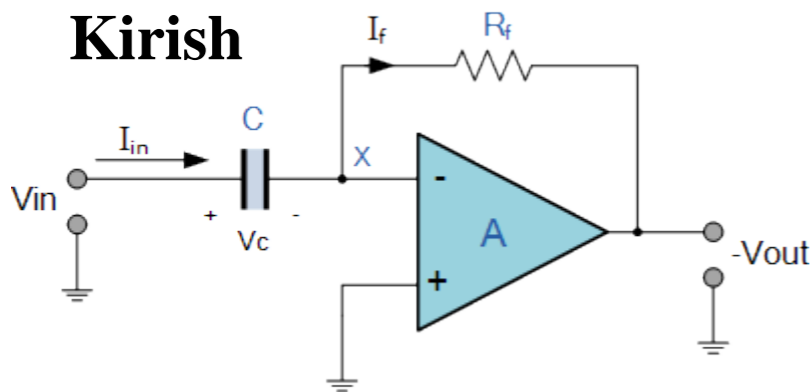


Photo source: [19] - <https://www.electronicstutorials.ws/wp-content/uploads/2013/08/opamp35.gif>

Qayta aloqa konturida

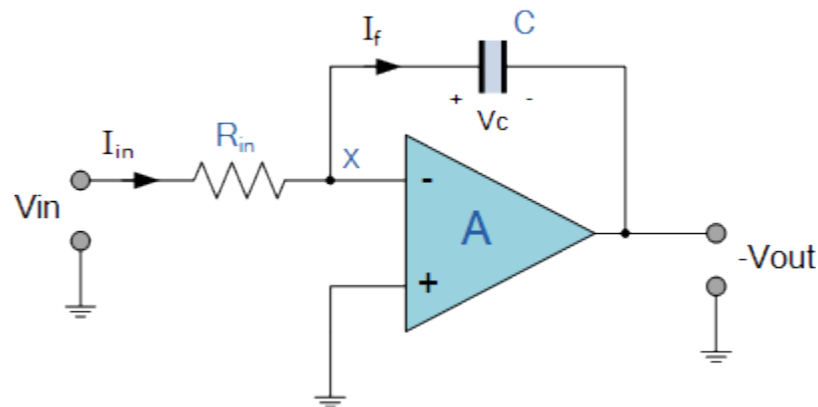


Photo source: [20] - <https://www.electronicstutorials.ws/wp-content/uploads/2013/08/opamp26.gif>

1st Order OP Amp Circuits: General Method 1

Node 1

$v_C = ?$
 $i_C = ?$
 $\tau = R_1 C$

Node ①

$i_{IN} = i_{OUT}$
 $i_{R1} = i_C$
 $\frac{-v_1}{R_1} = \frac{dv_C}{dt}$ ← ?

$v_2 = v_3$ $v_1 = v_2$

$? \rightarrow i_C = C \frac{dv}{dt}$ $i_{R1} = \frac{\Delta V}{R_1} = \frac{0 - v_1}{R_1}$

Photo source: [22] - <https://i.ytimg.com/vi/LM8unLMlabM/hqdefault.jpg>

Chiqish

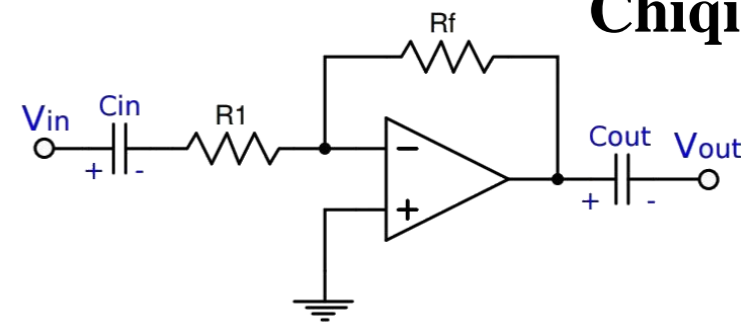
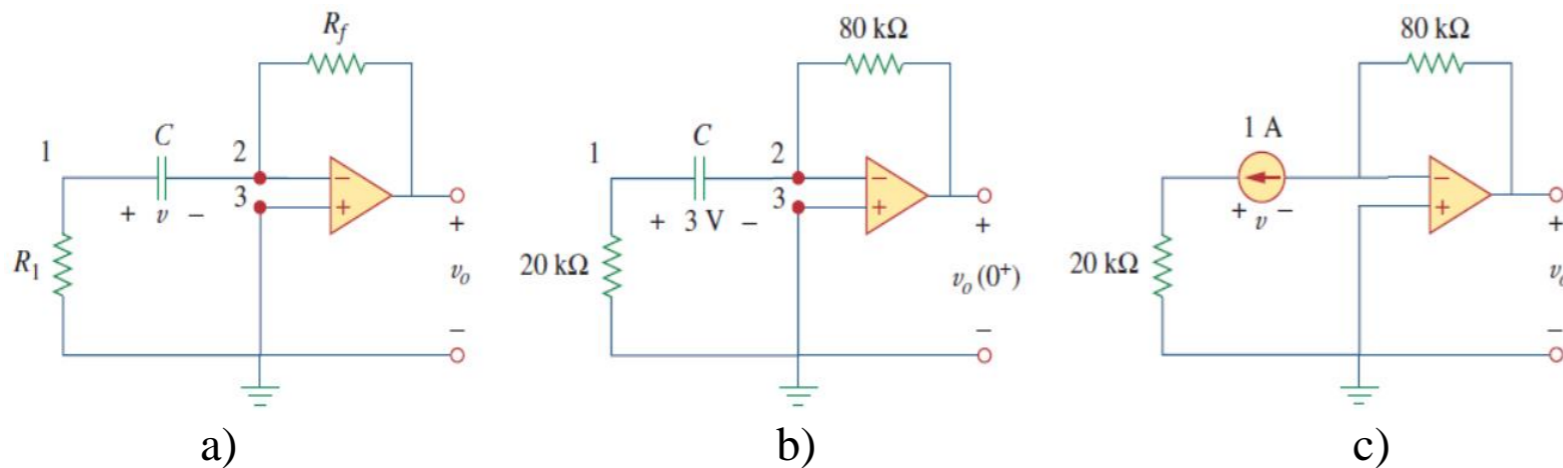


Photo source: [21] - <https://electrosome.com/wp-content/uploads/2016/12/AC-Coupled-Inverting-Amplifier-using-Opamp.jpg>

7.7.1-masala: 7.34-rasm, a) dagi operatsion kuchaytirgich zanjiri uchun

$u(0) = 3\text{ V}$ ekanligini hisobga olgan holda $t > 0$ uchun u_0 ni toping.

$R_f = 80\text{ k}\Omega$, $R_1 = 20\text{ k}\Omega$ va $C = 5\text{ }\mu\text{F}$ bo'lsin.



7.34-rasm.

Yechish:

1-tugun KCL: $u_1 \frac{0-u_1}{R_1} = C \frac{du}{dt}$

$$u_1 - u_2 = u; \quad u_2 = 0$$

$$u_1 - 0 = u \quad u_1 = u$$

$$\frac{du}{dt} + \frac{u}{CR_1} = 0$$

2 va 3 tugunlari bir xil potentsialga ega.

2-tugundagi potentsial nolga teng.

$$u(t) = U_0 e^{-\frac{t}{\tau}} \quad \tau = R_1 C$$

$$u(t) = 3e^{-10t}$$

$$u(0) = 3 = U_0$$

$$\tau = 20 \cdot 10^3 \cdot 5 \cdot 10^{-6} = 0,1.$$

2-tugun KCL: $C \frac{du}{dt} = \frac{0 - u_0}{R_f} \quad u_0 = -R_f C \frac{du}{dt}$

$$u_0 = -80 \cdot 10^3 \cdot 5 \cdot 10^{-6} (-30e^{-10t}) = 12e^{-10t} \text{ V}, \quad t > 0$$

U_0 - kondensator dagi dastlabki kuchlanish

7.8. Qo'llanilishi.

RC va RL zanjirlari qo'llaniladigan turli xil qurilmalarga o'zgarmas tok manbalarida filtrlash, raqamli aloqada bartaraf qilish zanjirlarini, differensiatorlar, integratorlar, kechikish zanjirlari va rele zanjirlari kiradi.

Bularning ba'zilar RC yoki RL zanjirlarining qisqa yoki uzoq muddatli konstantalaridan foydalanadi.

Bu yerda biz to'rtta oddiy dasturni ko'rib chiqamiz.

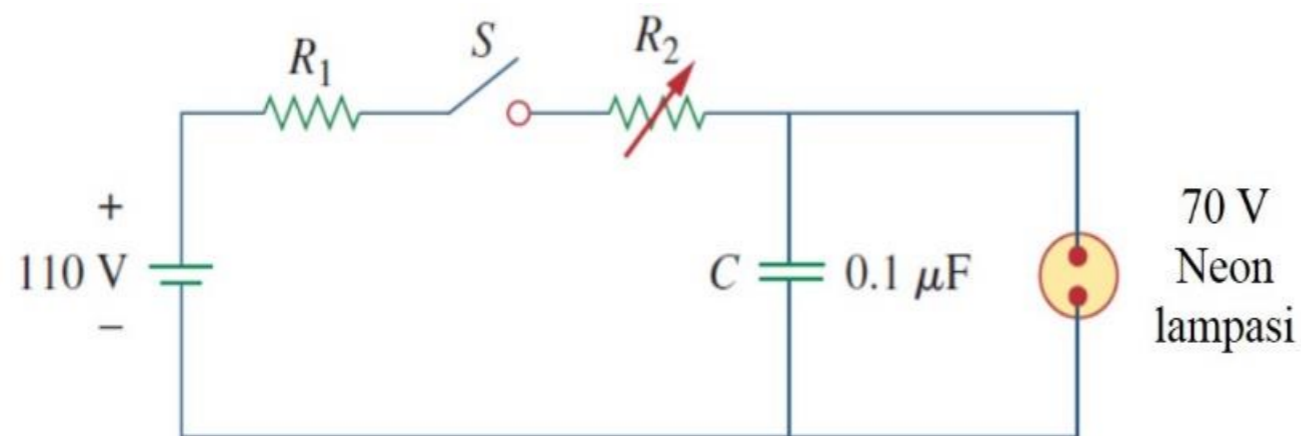
Birinchi ikkitasi RC zanjirlari, keyingilari RL zanjirlari.

Kechikish zanjirlari. RC zanjiri turli vaqt kechikishlarini ta'minlash uchun ishlatilishi mumkin.

Kuchlanish manbai chiroqni yoqish uchun yetarli kuchlanishni ta'minlaydi.

Kalit yopilganda, kondensator kuchlanishi zanjirning vaqt doimiysi $(R_1 + R_2)C$ bilan belgilanadigan tezlikda asta-sekin 110 V ga oshadi.

Chiroq kuchlanish 70 V ga oshmaguncha yorug'lik chiqarmaydi.



7.35-rasm. RC kechikish zanjiri.

Chiroqni har safar vaqt doimiysida $\tau = (R_1 + R_2)C$ qayta zaryadlash va qayta yoqishimiz mumkin.

τ vaqtida

Lampochka

$u_C <$
o'chirish

$u_C >$
yoqish

Yo‘l qurilish maydonchalarida tez-tez uchraydigan ogohlantirish miltillovchilari bunday RC kechikish zanjirining foydaliligiga misol bo‘la oladi.



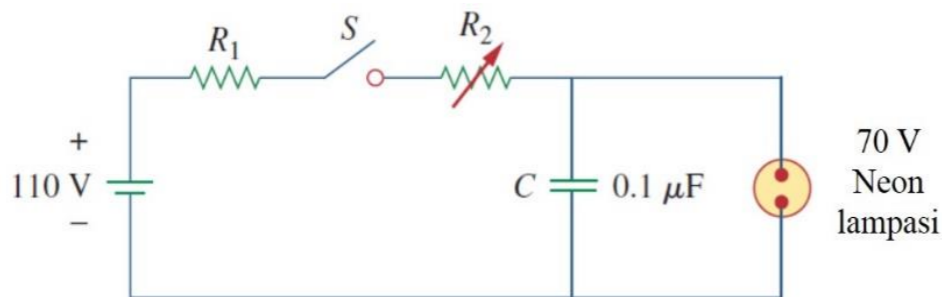
Photo source: [23] -
<https://www.guardiancouplings.com/-/media/Images/Corporate/Market/Category-Images/Mobile-Off-Highway/app-mobile-signs-lights.ashx?h=615&la=en&w=973&hash=6612EF53429DC41B659B49371AA81AAD49E9AB9D>

7.36-rasm. Yo‘l qurilish maydonchalaridagi miltillovchi chiroqlar.

7.8.1-masala: 7.35-rasmdagi zanjirni ko‘rib chiqing va $R_1 = 1,5 M\Omega$, $0 < R_2 < 2,5 M\Omega$

deb faraz qiling. a) Zanjirning vaqt konstantasining ekstremal chegaralarini hisoblang.

b) Kalit yopilgandan keyin birinchi marta chiroq qancha vaqt yonadi? R_2 eng katta qiymatini qabul qilaylik.



7.35-rasm. RC kechikish zanjiri.

b) $u_c(0) = 0$, esa $u_c(\infty) = 110$. Lekin,

$$u_c(t) = u_c(\infty) + [u_c(0) - u_c(\infty)]e^{-\frac{t}{\tau}} = 110[1 - e^{-\frac{t}{\tau}}]$$

bu yerda: $\tau = 0,4$ s. Chiroq $u_c = 70$ V kuchlanishda yonadi.

Agar $u_c(t) = 70$ V $t = t_0$ da bo‘lsa, u holda

$$70 = 110[1 - e^{-\frac{t_0}{\tau}}] \quad \rightarrow \quad \frac{7}{11} = 1 - e^{-\frac{t_0}{\tau}}$$

Yechish:

a) R_2 ning eng kichik qiymati 0Ω va zanjir uchun mos keladigan vaqt doimiysi:

$$\tau = (R_1 + R_2)C = (1,5 \cdot 10^6 + 0) \cdot 0,1 \cdot 10^{-6} = 0,15 \text{ s}$$

R_2 ning eng katta qiymati $2,5 M\Omega$ va zanjir uchun mos keladigan vaqt doimiysi:

$$\tau = (R_1 + R_2)C = (1,5 + 2,5) \cdot 10^6 \cdot 0,1 \cdot 10^{-6} = 0,4 \text{ s}$$

yoki,
$$e^{-\frac{t_0}{\tau}} = \frac{4}{11} \quad \rightarrow \quad e^{-\frac{t_0}{\tau}} = \frac{11}{4}$$

Har ikki tomonning natural logarifmini olsak,

$$t_0 = \tau \ln \frac{11}{4} = 0,4 \ln 2,75 = 0,4046 \text{ s}$$

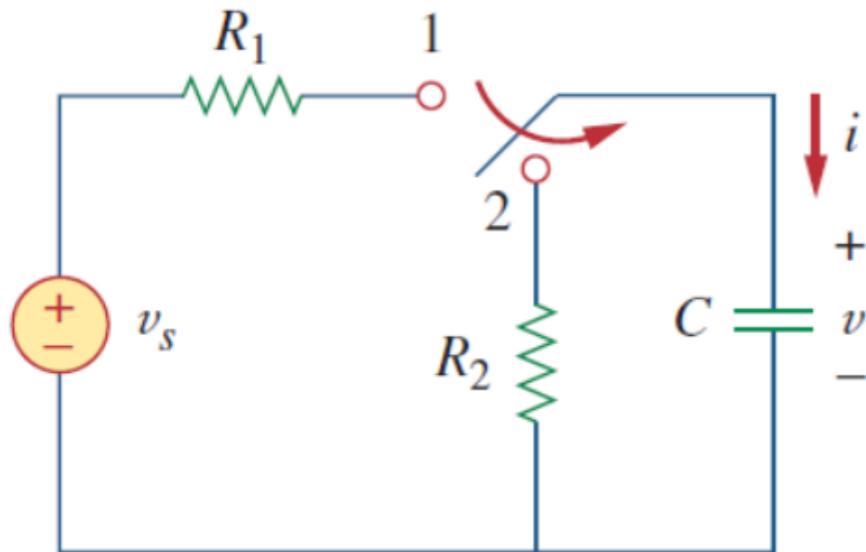
t_0 ni topishning umumiy formulasi:

$$t_0 = \tau \ln \frac{-u(\infty)}{u(t_0) - u(\infty)}$$

Chiroq, agar $u(t_0) < u(\infty)$ bo‘lsa, har t_0 soniyada qayta-qayta yonadi.

Photoflash birligi. Elektron flash birligi RC zanjirining umumiy misolini beradi.

Ushbu dastur kondensatorning kuchlanishdagi har qanday keskin o'zgarishlarga qarshi turish qobiliyatidan foydalanadi.

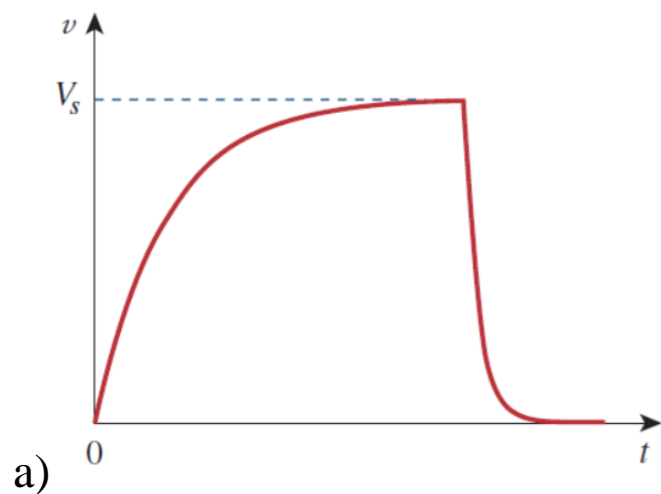


U asosan yuqori kuchlanishli o'zgarmas tok manbai, tok kuchini cheklovchi yuqori R_1 rezistor va past R_2 rezistor chirog'i bilan parallel ravishda kondensator C dan iborat.

Kalit 1-holatda bo'lsa, kondensator uzoq vaqt doimiyligi $\tau_1 = R_1 C$ tufayli sekin zaryadlanadi.

7.37-rasm.

1-holatda sekin zaryadlashni va 2-holatda esa tez zaryadsizlanishni ta'minlaydigan miltillovchi qurilma uchun zanjir.

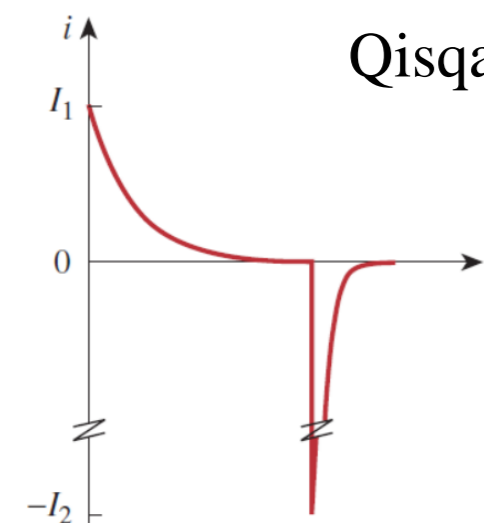


Kondensator kuchlanishi asta-sekin noldan U_s gacha ko‘tariladi, uning tok kuchi esa $I_1 = U_s/R_1$ dan nolga asta-sekin kamayadi.

Zaryadlash vaqti doimiy vaqtdan taxminan besh marta ko‘p talab etiladi.

$$t_{zaryad} = 5R_1C \quad (7.64)$$

Kalit 2-holatda bo‘lsa, kondensator kuchlanishi razryadlanadi.



Qisqa vaqt ichida cho‘qqisi $I_2 = U_s/R_2$ bo‘lgan yuqori razryadlanish tokiga imkon beradi.

Razryadlanish doimiy vaqtdan taxminan besh baravar tez sodir bo‘ladi.

$$t_{razryadlanish} = 5R_2C \quad (7.65)$$

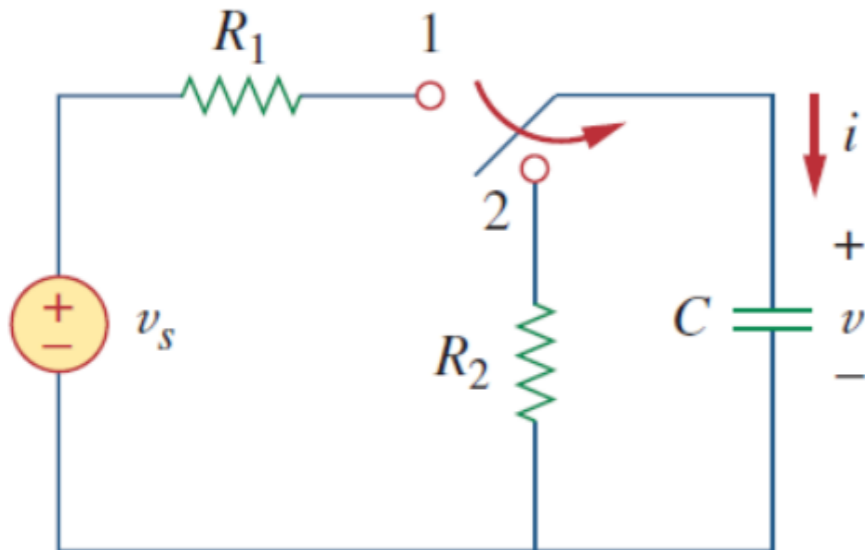
7.38-rasm.

a) kondensator kuchlanishini sekin zaryadlanishi va tez razryadlanishi,

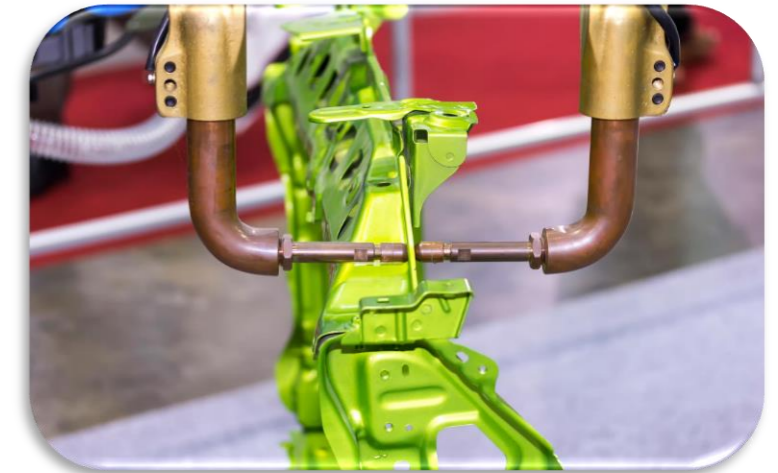
b) kondensatordagi tok kuchini sekin zaryadlanish toki $I_1 = U_s/R_1$ va yuqori razryadlanish toki $I_2 = U_s/R_2$.

Shunday qilib, 7.37-rasmdagi oddiy RC zanjiri qisqa muddatli, yuqori tok pulsini ta'minlaydi.

Bunday zanjir nuqtali (kontaktli) elektr payvandlashda va radar uzatuvchi trubkasida ham qo'llaniladi (7.39-rasm).



7.37-rasm.



7.39-rasm. Nuqtali (kontaktli) elektr payvandlash qurilmasi.

Photo source: [24] - <https://www.wcwelding.com/images/chicag-o-electric-spot-welder.jpg>

Photo source: [25] - <https://www.twi-global.com/image-library/hero/spot-welding-istock-1137289766.jpg>



7.8.2-masala: Elektron miltillovchi tokni cheklovchi 6Ω qarshilik va $2000 \mu\text{F}$

elektrolitik kondensator 240 V da zaryadlangan. Chiroq qarshiligi 12Ω bo'lsa, quyidagilarni toping.

Yechish:

a) Maksimal zaryadlash tok kuchi.

$$I_1 = \frac{U_s}{R_1} = \frac{240}{6 \cdot 10^3} = 40 \text{ mA}$$

c) Maksimal razryadlanish tok kuchi.

$$I_2 = \frac{U_s}{R_2} = \frac{240}{12} = 20 \text{ mA}$$

e) Kondensatorida saqlanadigan energiya razryadlanish davrida chiroq bo'ylab tarqaladi.

$$t_{\text{razryadlanish}} = 5R_2C = 5 \cdot 12 \cdot 2000 \cdot 10^{-6} = 0,12 \text{ s}$$

b) Zaryadlanish vaqtini hisoblaymiz.

$$t_{\text{zaryad}} = 5R_1C = 5 \cdot 6 \cdot 10^3 \cdot 2000 \cdot 10^{-6} = 60 \text{ s} = 1 \text{ minut}$$

d) Saqlangan energiya.

$$W = \frac{1}{2}CU_s^2 = \frac{1}{2} \cdot 2000 \cdot 10^{-6} \cdot 240^2 = 57,6 \text{ J}$$

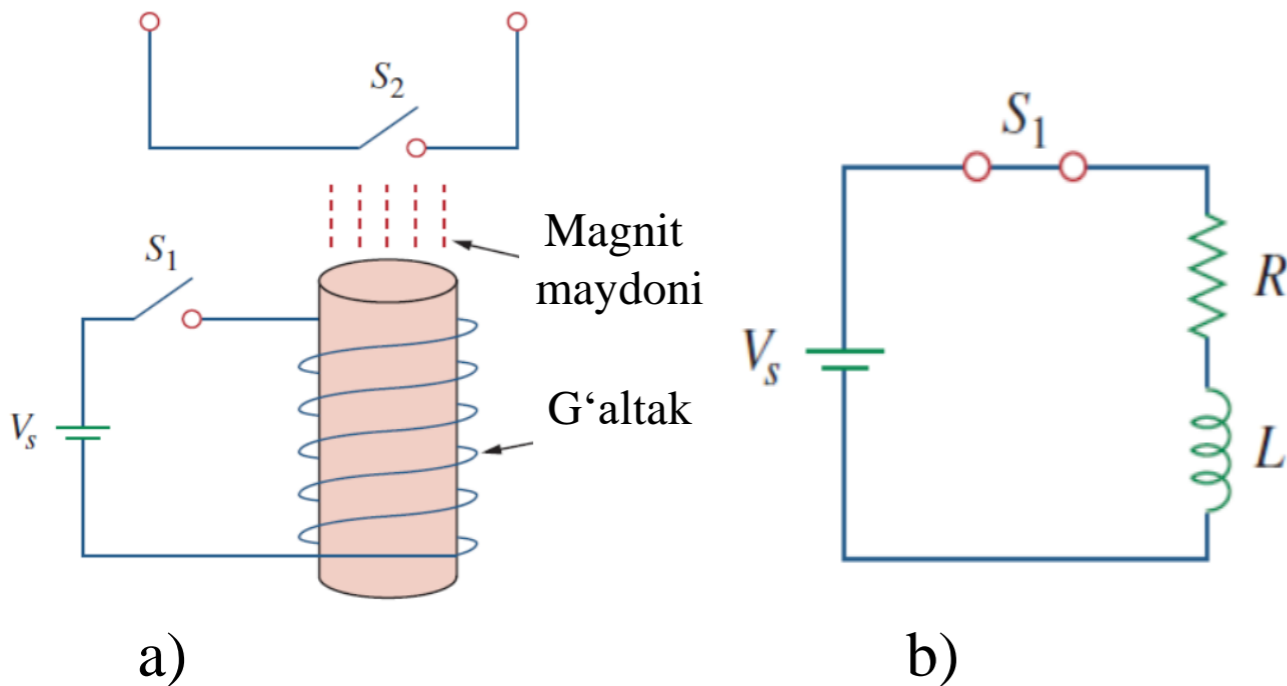
Shunday qilib, sarflanadigan o'rtacha quvvat.

$$p = \frac{W}{t_{\text{razryadlanish}}} = \frac{57,6}{0,12} = 480 \text{ Vt}$$

Rele zanjirlari. Magnit bilan boshqariladigan kalitga *rele* deyiladi. Rele asosan boshqa zanjirlar tomonidan boshqaruvchi kalitni ochish yoki yopish uchun ishlatiladigan elektromagnit qurilmadir.

S_1 kalit yopilganda, g'altak zanjiri quvvatlanadi.

G'altak tok kuchi asta-sekin o'sib boradi va magnit maydonini hosil qiladi.



7.40-rasm. Rele zanjiri.

Natijada magnit maydon boshqa zanjirdagi harakatlanuvchi kontakti tortib oladi va S_2 kalitini yopish uchun yetarlicha kuchli bo'ladi.

Bu vaqtda rele tortilgan deb qaraladi. S_1 va S_2 kalitlarining yopilishi orasidagi vaqt oralig'i t_d releni *kechikish vaqti* deb ataladi.



7.8.3-masala: Muayyan rele g'altagi 12 V batareya bilan ishlaydi. G'altakning

qarshiligi 150Ω va induktivligi 30 mH va tortish uchun zarur bo'lgan tok 50 mA bo'lsa, rele kechikish vaqtini hisoblang.

Yechish:

G'altak orqali o'tadigan tok kuchi quyidagi bilan aniqlanadi.

$$i(t) = i(\infty) + [i(0) - i(\infty)]e^{-\frac{t}{\tau}}$$

$$i(0) = 0, \quad i(\infty) = \frac{12}{150} = 80 \text{ mA}; \quad \tau = \frac{L}{R} = \frac{30 \cdot 10^{-3}}{150} = 0,2 \text{ ms}$$

Ikkala tomonning natural logarifmini olsak,

$$t_d = \tau \ln \frac{8}{3} = 0,2 \ln \frac{8}{3} \text{ ms} = 0,1962 \text{ m s}$$

$$i(t) = 80[1 - e^{-\frac{t_d}{\tau}}] \text{ mA} \quad \text{Agar, } i(t_d) = 50 \text{ mA bo'lsa,}$$

$$50 = 80[1 - e^{-\frac{t_d}{\tau}}] \quad \rightarrow \quad \frac{5}{8} = 1 - e^{-\frac{t_d}{\tau}}$$

Shu bilan bir qatorda, biz t_d ni quyidagi yordamida topishimiz mumkin.

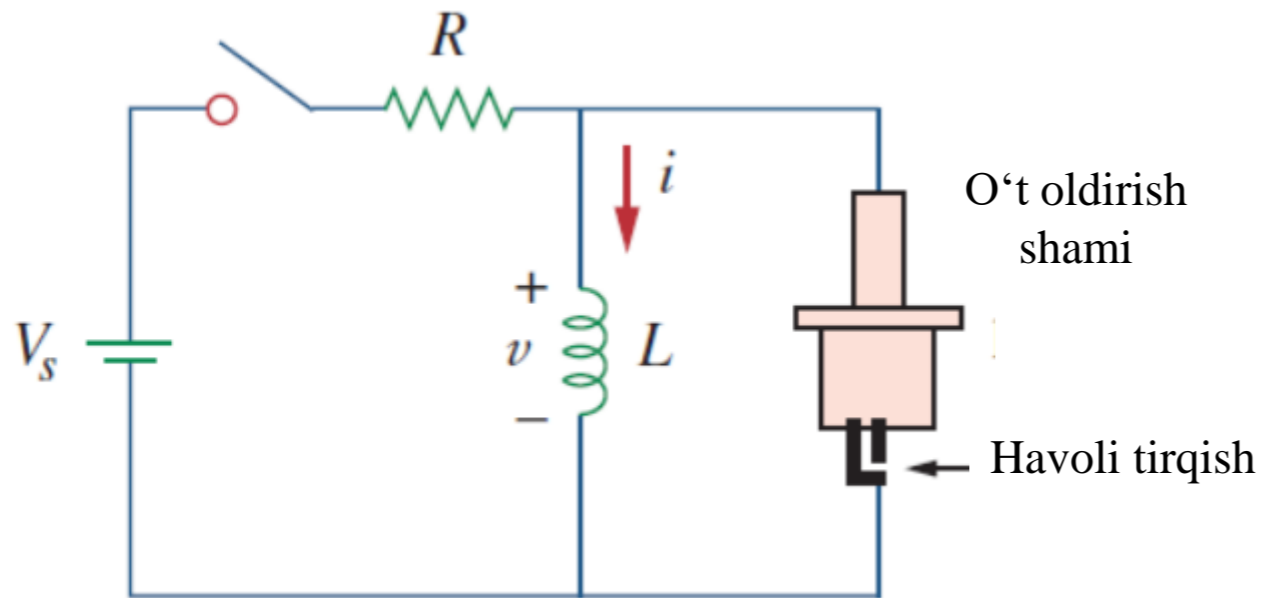
yoki,

$$-e^{-\frac{t_d}{\tau}} = \frac{3}{8} \quad \rightarrow \quad e^{-\frac{t_d}{\tau}} = \frac{8}{8}$$

$$t_d = \tau \ln \frac{i(0) - i(\infty)}{i(t_d) - i(\infty)}$$

Avtomobilni o‘t oldirish tizimi. Induktorlarning tok kuchi tez o‘zgarishiga qarshi turish qobiliyati ularni yoy yoki uchqun hosil qilish uchun foydali qiladi. Avtomobilni o‘t oldirish tizimi bu xususiyatdan foydalanadi.

Avtomobilning benzinli dvigateli har bir silindrdagi yoqilg‘i-havo aralashmasini o‘z vaqtida yoqishni talab qiladi.



Bunga asosan havo bo‘shlig‘i bilan ajratilgan bir juft elektroddan iborat bo‘lgan o‘t oldirish shami orqali erishiladi.

7.41-rasm. Avtomobil o‘t oldirish tizimining elektr zanjiri.

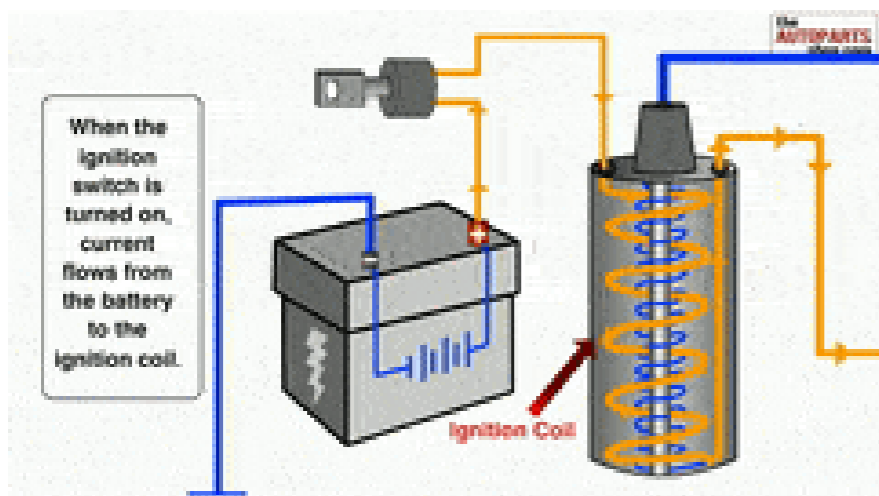


Photo source: [26] -

<https://thumbs.gfycat.com/WhiteOpenDogwoodtwigborer-max-1mb.gif>

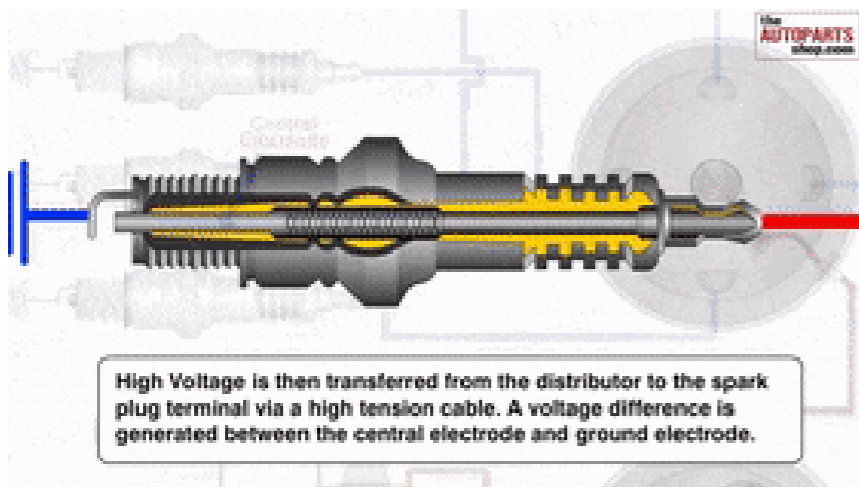


Photo source: [27] -

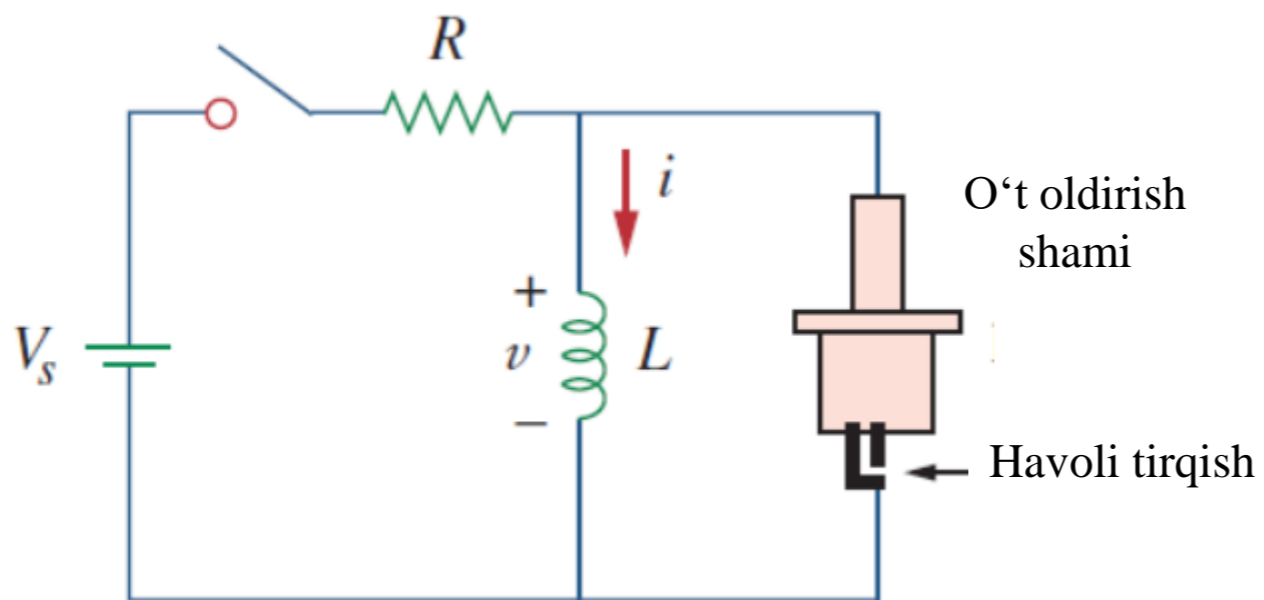
<https://thumbs.gfycat.com/SlipperyShinyBedbug-max-1mb.gif>

Elektrodlar o'rtasida katta kuchlanishni hosil qilib, havo bo'shlig'ida uchqun hosil bo'ladi va shu bilan yoqilg'ini yoqadi.

Ammo atigi 12 V kuchlanishni ta'minlaydigan avtomobil akkumulyatoridan bunday katta kuchlanishni qanday olish mumkin?

Bunga induktor (uchqun g'altagi) L orqali erishiladi.

Induktordagi kuchlanish $u = L di/dt$ bo'lgani uchun, biz juda qisqa vaqt ichida tok kichining katta o'zgarishini yaratib, di/dt ni katta qilishimiz mumkin.



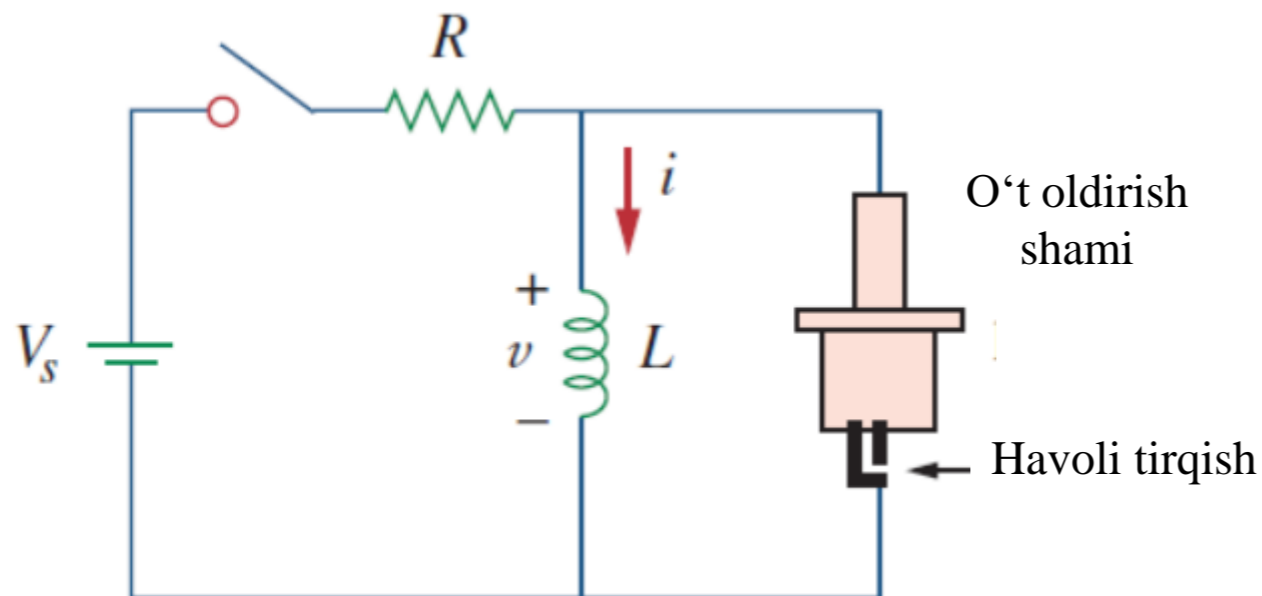
O‘t oldirish kaliti berkilganda, induktor orqali tok kuchi asta-sekin o‘shib boradi va $i = U_s/R$ ning yakuniy qiymatiga yetadi, bu yerda $U_s = 12\text{ V}$.

Elektr janjirining vaqt konstantasi induktorni zaryad qilish uchun besh baravar ko‘p vaqt kerak bo‘ladi ($\tau = L/R$),

$$t_{zaryad} = 5 \frac{L}{R} \quad (7.66)$$

7.8.4-masala: Qarshiligi 4Ω va induktivligi 6 mH bo‘lgan solenoid 7.41-rasmdagiga o‘xshash

avtomobil o‘t oldirish tizimida ishlatiladi. Agar batareya 12 V quvvat bersa, quyidagilarni aniqlang: kalit yopilganda solenoid orqali o‘tadigan oxirgi tok kuchi, g‘altakda saqlanadigan energiya va havo bo‘shlig‘idagi kuchlanish, kalitni ochish uchun $1 \mu\text{s}$ kerak bo‘ladi deb tasavvur qiling.



Yechish:

G‘altak orqali o‘tuvchi so‘ngi tok kuchi,

$$I = \frac{U_s}{R} = \frac{12}{4} = 3 \text{ A}$$

G‘altakda saqlangan energiya,

$$W = \frac{1}{2} LI^2 = \frac{1}{2} \cdot 6 \cdot 10^{-3} \cdot 3^2 = 27 \text{ mJ}$$

Bo‘shliqdagi kuchlanish,

$$U = L \frac{\Delta I}{\Delta t} = 6 \cdot 10^{-3} \cdot \frac{3}{1 \cdot 10^{-6}} = 18 \text{ kV}$$

7.41-rasm. Avtomobil o‘t oldirish tizimining elektr zanjiri.

FOYDALANILGAN MANBALAR:

16. <https://media.cheggcdn.com/media/c49/c495773b-5c61-4a1d-84f6-afea651859d5/php9Rsuc1>
17. <https://www.electronics-tutorials.ws/wp-content/uploads/2018/05/opamp-opamp51.gif>
18. https://www.cpp.edu/~elab/projects/project_08/images/Thevenin-1.gif
19. <https://www.electronics-tutorials.ws/wp-content/uploads/2013/08/opamp35.gif>
20. <https://www.electronics-tutorials.ws/wp-content/uploads/2013/08/opamp26.gif>
21. <https://electrosome.com/wp-content/uploads/2016/12/AC-Coupled-Inverting-Amplifier-using-Opamp.jpg>
22. <https://i.ytimg.com/vi/LM8unLMlabM/hqdefault.jpg>
23. <https://www.guardiancouplings.com/-/media/Images/Corporate/Market/Category-Images/Mobile-Off-Highway/app-mobile-signs-lights.ashx?h=615&la=en&w=973&hash=6612EF53429DC41B659B49371AA81AAD49E9AB9D>
24. <https://www.wcwelding.com/images/chicago-electric-spot-welder.jpg>
25. <https://www.twi-global.com/image-library/hero/spot-welding-istock-1137289766.jpg>
26. <https://thumbs.gfycat.com/WhiteOpenDogwoodtwigborer-max-1mb.gif>
27. <https://thumbs.gfycat.com/SlipperyShinyBedbug-max-1mb.gif>

TEKSHIRISH UCHUN SAVOLLAR!

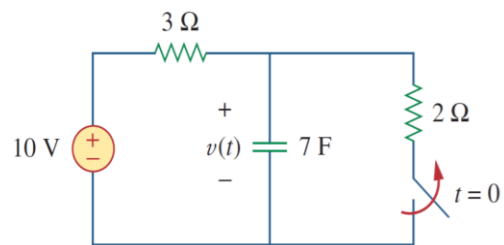
7.1. RC sxemasi $R = 2 \Omega$ va $C = 4 F$ ga ega. Vaqt doimiysi:
 A) 0,5 s. B) 2 s. C) 4 s. D) 8 s. E) 15 s.

7.2. RL sxemasi $R = 2 \Omega$ va $L = 4 H$ ga ega. Vaqt doimiysi:
 A) 0,5 s. B) 2 s. C) 4 s. D) 8 s. E) 15 s.

7.3. $R = 2 \Omega$ va $C = 4 F$ bo'lgan RC zanjiridagi kondensator zaryadlanmoqda. Kondensator kuchlanishining barqaror holat qiymatining 63,2 foiziga yetishi uchun zarur bo'lgan vaqt:
 A) 2 s. B) 4 s. C) 8 s. D) 16 s. E) hech qaysisi.

7.4. RL zanjirida $R = 2 \Omega$ va $L = 4 H$ bo'ladi. Induktor tok kuchi uning barqaror holat qiymatining 40 foiziga yetishi uchun zarur bo'lgan vaqt:
 A) 0,5 s. B) 1 s. C) 2 s. D) 4 s. E) hech qaysisi.

7.5. 7.42-rasmdagi zanjirda $t = 0$ dan oldingi kondensator kuchlanishi:

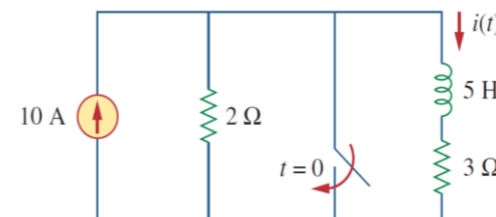


7.42-rasm.

- A) 10 V.
- B) 7 V.
- C) 6 V.
- D) 4 V.
- E) 0 V.

7.6. 7.42-rasmdagi zanjir uchun $u(\infty)$:
 A) 10 V. B) 7 V. C) 6 V. D) 4 V. E) 0 V.

7.7. 7.43-rasmdagi zanjirda $t = 0$ dan oldingi induktor tok kuchi:



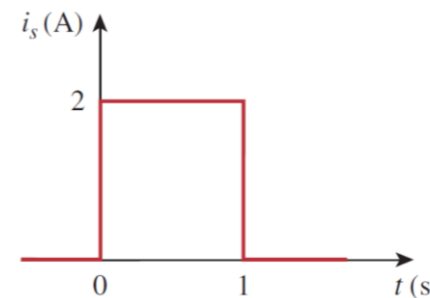
7.43-rasm.

- A) 8 A.
- B) 6 A.
- C) 4 A.
- D) 2 A.
- E) 0 A.

7.8. 7.43-rasmdagi zanjir uchun $i(\infty)$:
 A) 10 A. B) 6 A. C) 4 A. D) 2 A. E) 0 A.

7.9. Agar u_s $t = 0$ da 2 V dan 4 V ga o'zgarsa, u_s ni quyidagicha ifodalashimiz mumkin:
 A) $\delta(t)V$. B) $2u(t)V$. C) $2u(-t) + 4u(t)V$.
 D) $2 + 2u(t)V$. E) $4u(t) - 2V$.

7.10. 7.44-rasmdagi impulsni yakkalik funksiyalari bilan quyidagicha ifodalash mumkin:



7.44-rasm.

- A) $2u(t) + 2u(t - 1)V$.
- B) $2u(t) - 2u(t - 1)V$.
- C) $2u(t) - 4u(t - 1)V$.
- D) $2u(t) + 4u(t - 1)V$.



*E'TIBORINGIZ
UCHUN
RAHMAT!!!*