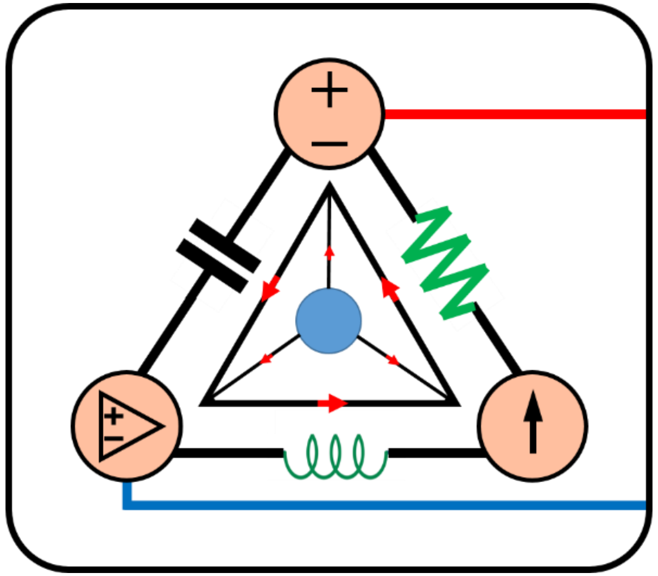
6-Mavzu: Kondensator va induktiv g‘altak.

(Lecture-6: Capacitors and Inductors)

6-Mavzuning 1-qismi

(Part 1 of the Lecture-6)



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6-Mavzu: Kondensator va induktiv g‘altak.

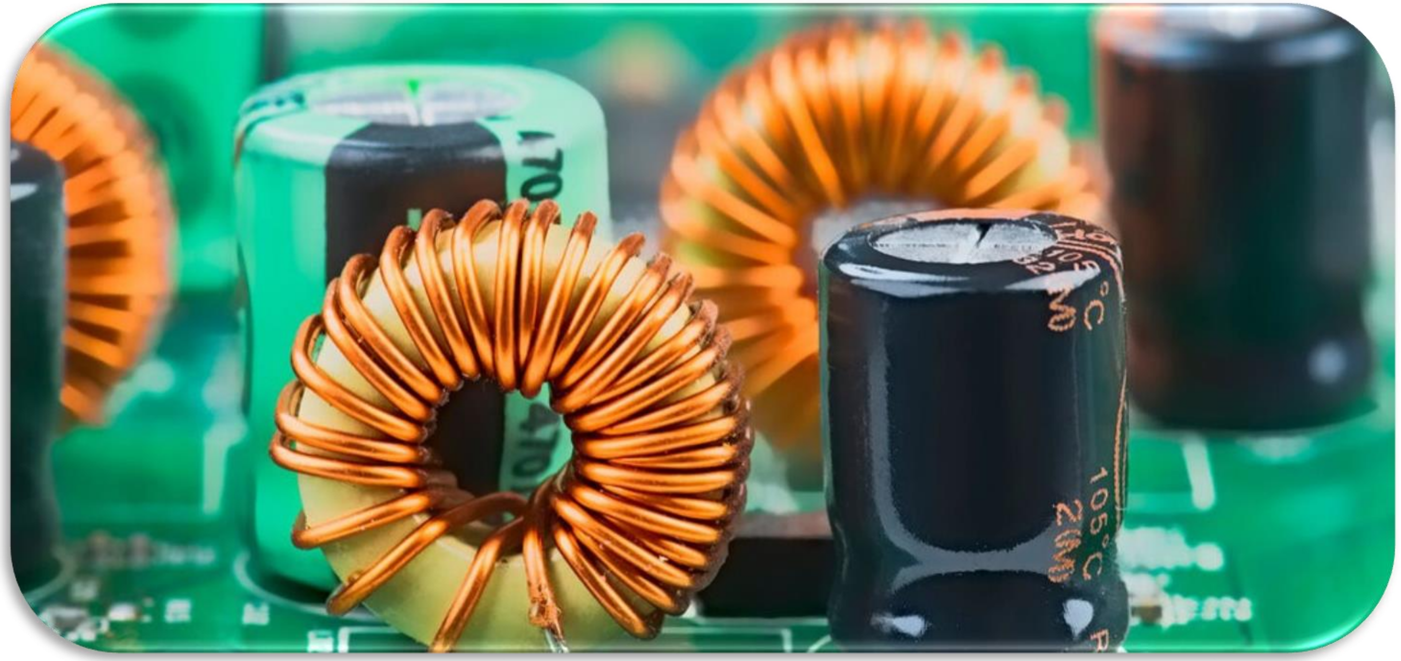
(Lecture-6: Capacitors and Inductors)

O‘quv rejasi:

6.1. Kondensatorlar.

Hozirgacha biz o‘rganishimizni qarshilik zanjirlari bilan chekladik. Bu mavzuda biz ikkita yangi va muhim passiv elementlarni o‘rganib chiqamiz: kondensator va induktor.

Energiyani yo‘qotadigan rezistorlardan farqli o‘laroq, kondensatorlar va induktorlar energiyani yo‘qotmaydi ya’ni tarqatmaydi.



Balki, energiyani saqlaydi (*to‘playdi*), ularni keyinroq qayta tiklash mumkin.

Shu sababli, kondensatorlar va induktorlar saqlash elementlari deb ataladi.

Photo source: [1] - https://electricala2z.com/wp-content/uploads/2018/03/capacitor-inductor-transformer.jpg

Rezistorli zanjirlarni qo‘llash juda cheklangan.

Kondensatorlarni vazifasi, ishlatilishi va ularni zanjirlarda qanday ulanishini tahlil qilamiz.

Kondensator *- bu elektr maydonida energiyani saqlash uchun mo‘ljallangan passiv elementdir.*

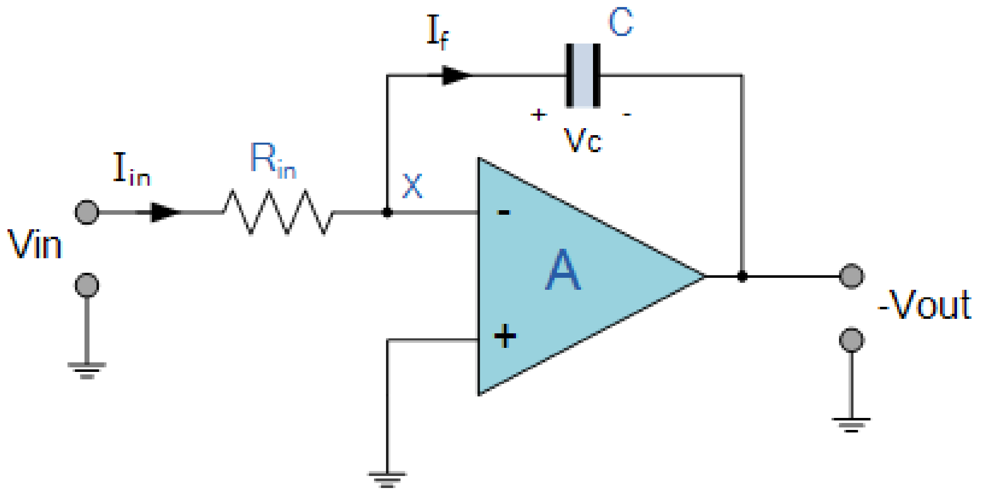
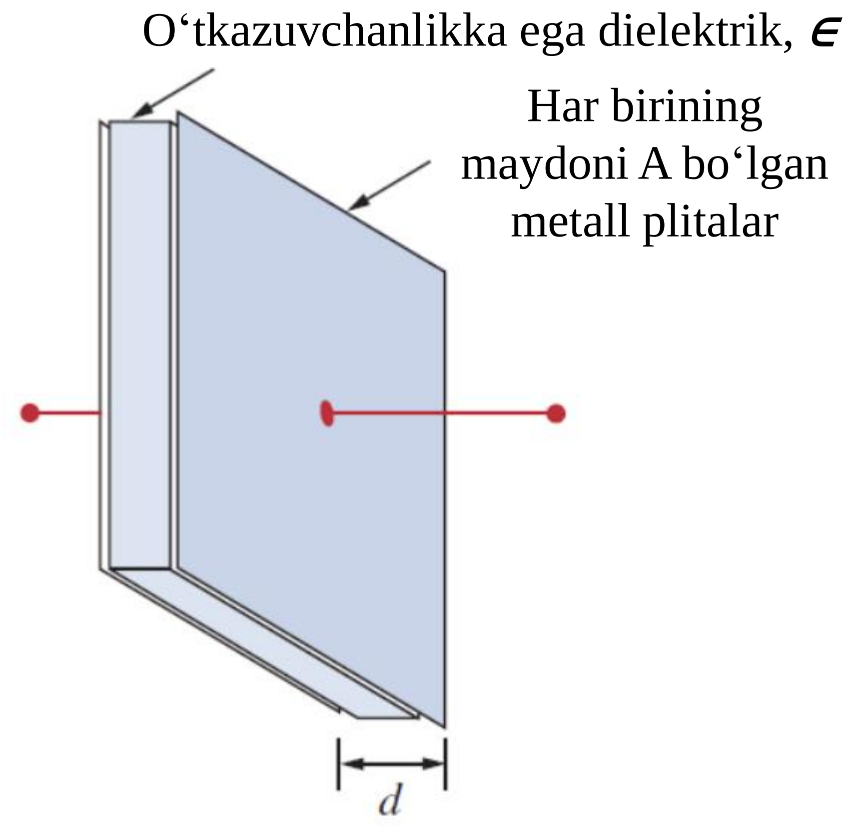


Photo source: [2] - https://www.electronics-tutorials.ws/wp-content/uploads/2013/08/opamp26.gif

Rezistorlardan tashqari, kondensatorlar eng keng tarqalgan elektr komponentlari hisoblanadi.

Photo source: [3] - https://www.shutterstock.com/image-vector/resistors-capacitors-inductors-symbols-passive-260nw-1954107442.jpg

Kondensatorlar elektronika, aloqa, kompyuterlar va energiya tizimlarida keng qo‘llaniladi. Masalan, ular radio qabul qiluvchilarning sozlash sxemalarida va kompyuter tizimlarida dinamik xotira elementlari sifatida ishlatiladi.



6.1-rasm. Oddiy kondensator.

Kondensator izolyator (yoki dielektrik) bilan ajratilgan ikkita o‘tkazuvchi plastinkadan iborat.

Amaliyotda plastinkalar alyumin folgadan tayyorlanadi. Dielektrik sifatida keramika, qog‘oz yoki slyuda ishlatiladi.

Kondensatorga kuchlanish manbai ulanganda, bir plastinkada musbat zaryad ($+q$), ikkinchisida ($-q$) manfiy zaryad joylashadi.

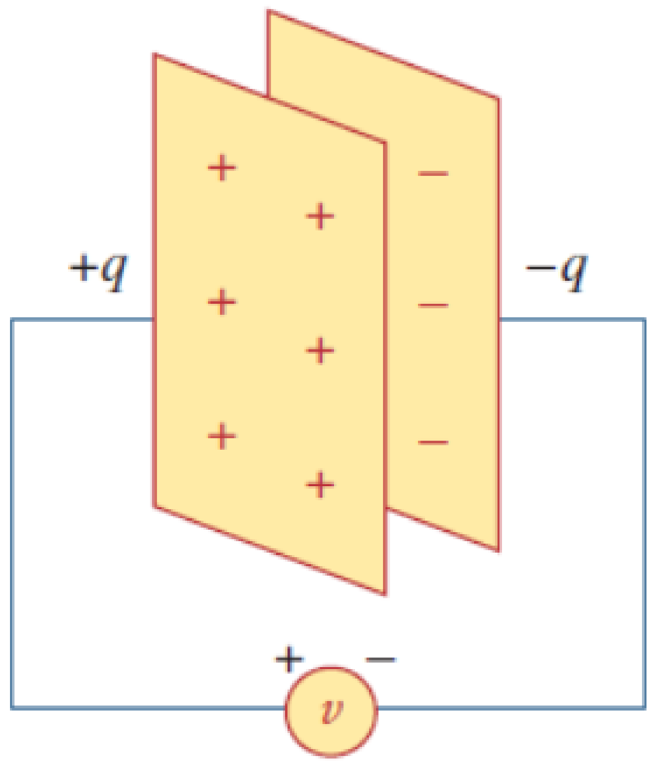
Kondensatorda saqlangan zaryad miqdori, q bilan ifodalangan, qo‘llaniladigan kuchlanish bilan to‘g‘ridan-to‘g‘ri proporsionaldir.

$$\boldsymbol{q = Cu} \qquad \textbf{(6.1)}$$

bu yerda: C - mutanosiblik doimiysi, kondensatorning sig‘imi deb nomlanadi.

$$C = 1\frac{kulon}{volt} = 1\,farad\ (F)$$

Sig‘imning birligini ingliz fizigi Maykl Faradey (1791-1867) sharafiga farad (F) deb belgilash kiritilgan.



6.2-rasm. Kondensatorni kuchlanish *U* bilan qo‘llanilishi.

Sig'im - bu kondensatorning bitta plitasidagi zaryadning ikki plastinka orasidagi kuchlanish farqiga nisbati bilan aniqlanadi.

$$C = \frac{Q}{U} \qquad (6.2a)$$

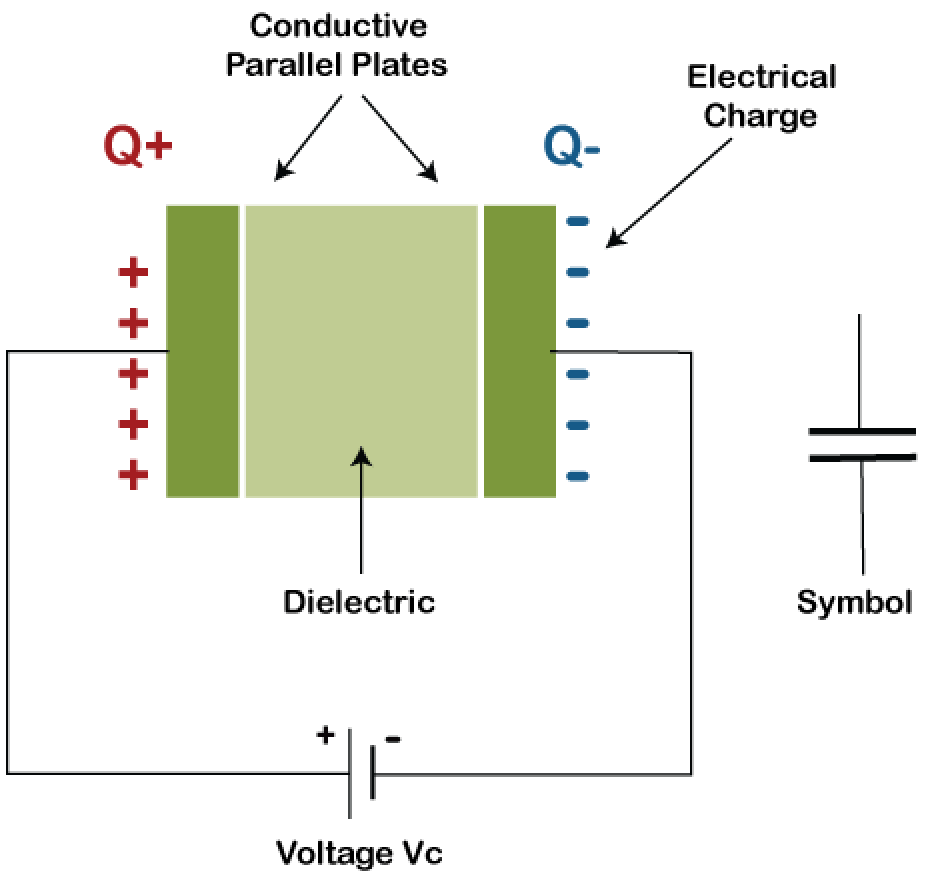


Photo source: [4] - https://static.javatpoint.com/blog/images/capacitor.png

bu yerda: Q – kondensator qoplamalarini birida yig'ilgan zaryad miqdori; U – kondensator qoplamalari orasidagi potensiallar farqi.

Aslida kondensatorda umumiy zaryad 0 ga teng. Chunki, uning qoplamalarida miqdor jihatdan bir xil lekin qarama-qarshi bo'lgan ishorali zaryadlar yig'iladi.

$$-Q = +Q \qquad (6.2b)$$

Kondensatorning sig‘imi C har bir plastinka uchun q zaryadining qo‘llaniladigan kuchlanishga nisbati bo‘lsa-da, u q ga bog‘liq emas. Balki, kondensatorning fizik o‘lchamlariga bog‘liq.

Izolyatsiya jismlarning dielektrik o‘tkazuvchanligi

Dielektrik	Dielektrik o‘tkazuvchanlik, ∈
Havo	1,0
Parafin	2,1 ÷2,3
Transformator	2,0 ÷2,5
Qog‘oz	3,0 ÷3,5
Slyuda	4,0 ÷7,5
Shisha	5,5 ÷10,0
Marmar	8,3
Rezina	3,5

$$C = \frac{\in A}{d} \qquad (6.2c)$$

bu yerda: A - har bir plastinkaning sirt maydoni, d - plitalar orasidagi masofa va ∈ - plitalar orasidagi dielektrik materialning o‘tkazuvchanligi.

Dielektrik so‘tkazuvchanlikni yunoncha ∈ (epsilon) bilan belgilash qabul qilingan.

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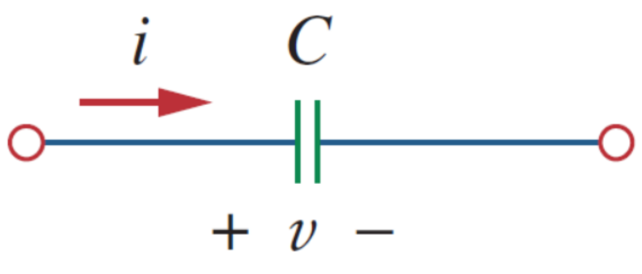
Sig‘im qiymatini uchta omil aniqlaydi:

1. Plastinkalarning sirt maydoni - maydon qanchalik katta bo‘lsa, sig‘im shunchalik katta bo‘ladi;

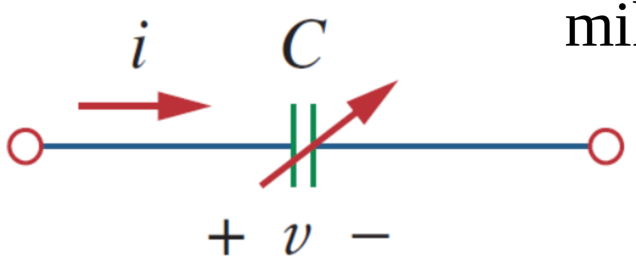
2. Plastinkalar orasidagi masofa - masofa qanchalik kichik bo‘lsa, sig‘im shunchalik katta bo‘ladi;

3. Materialning o‘tkazuvchanligi - o‘tkazuvchanlik qanchalik yuqori bo‘lsa, sig‘im shunchalik katta bo‘ladi.

Kondensatorlar pikofarad (pF) dan mikrofarad (μF) oralig‘ida qiymatlarga ega.



a)



b)

6.3-rasm. Kondensatorlarni zanjirdagi shakli.
a) o‘zgarmas kondensator, b) o‘zgaruvchan kondensator.

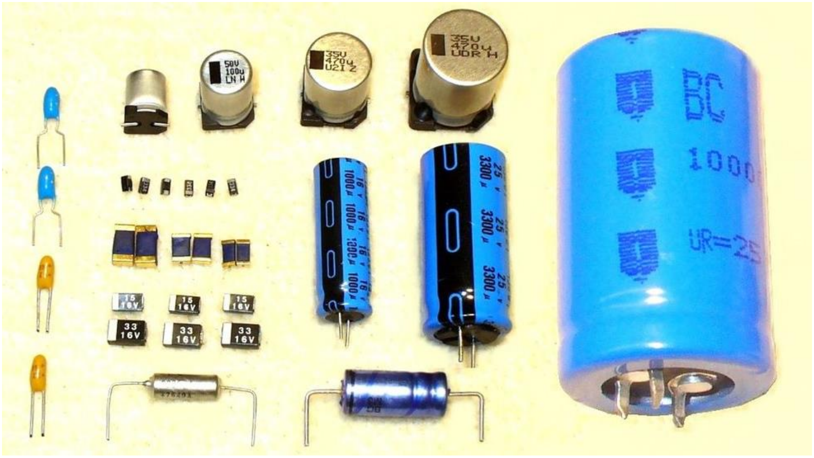
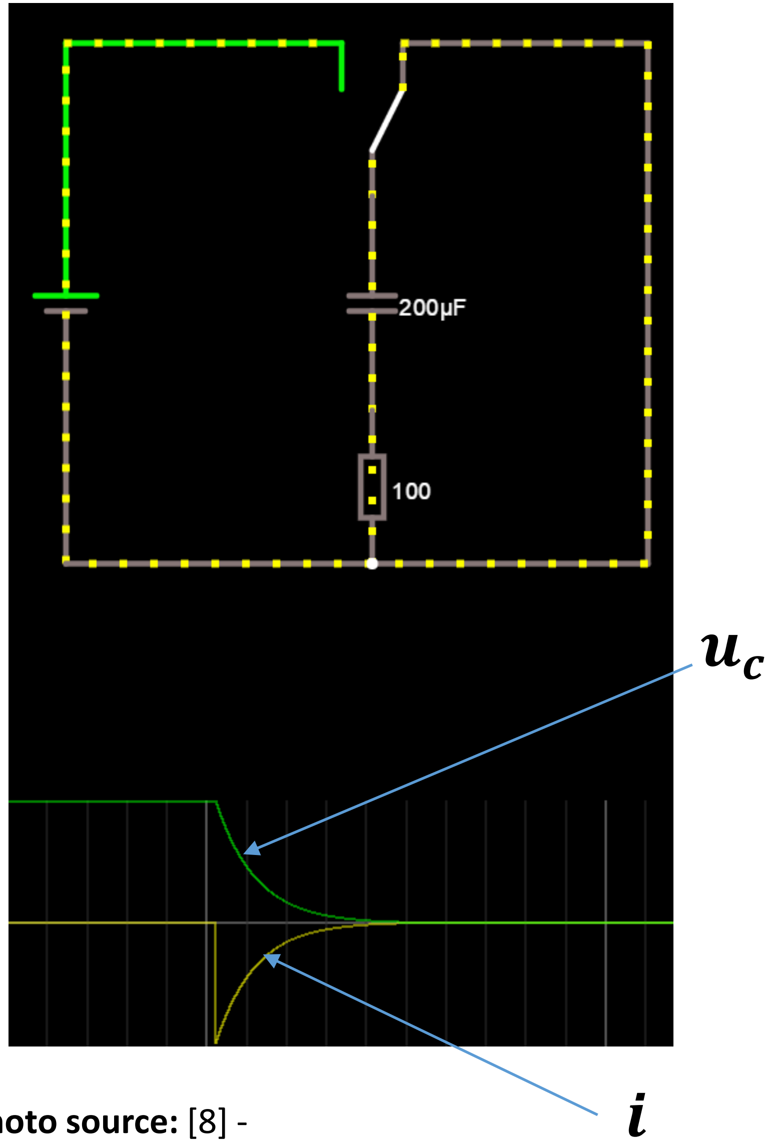
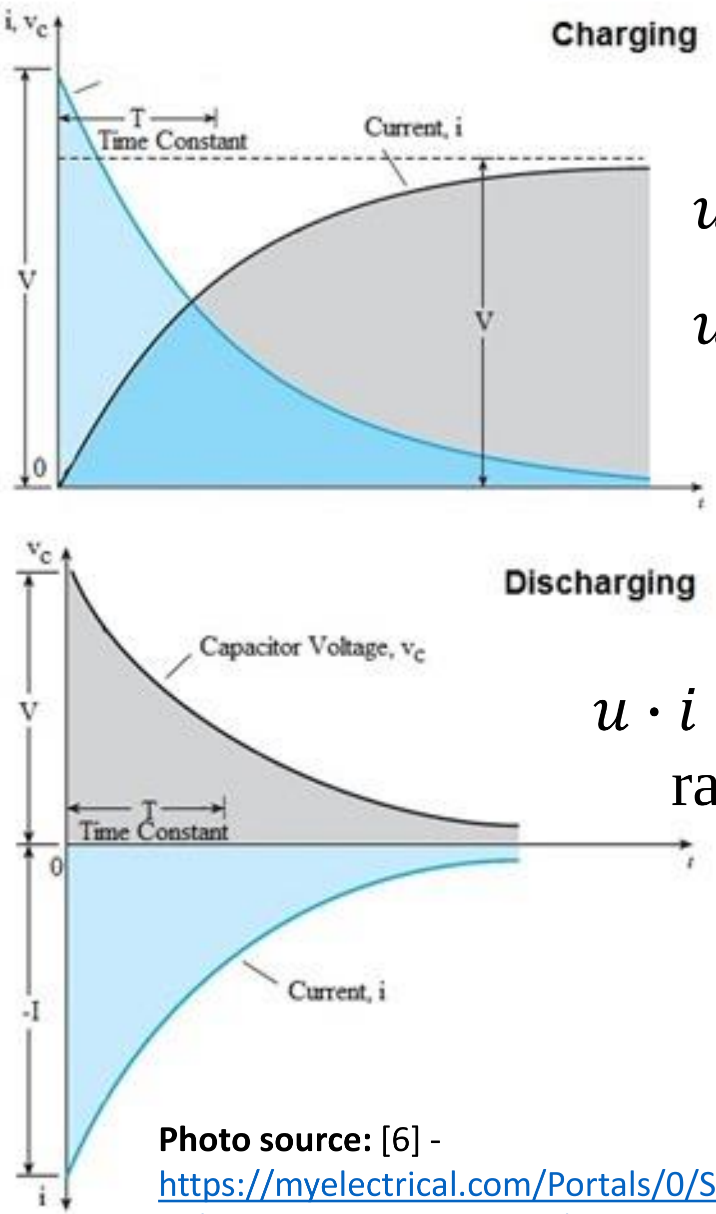


Photo source: [5] - https://upload.wikimedia.org/wikipedia/commons/thumb/f/f6/Electrolytic_capacitors-P1090328.JPG/1024px-Electrolytic_capacitors-P1090328.JPG

Passiv belgi konvensiyasiga ko‘ra,





$u > 0$ va $i > 0$

$u < 0$ va $i < 0$

zaryadlanish

$u \cdot i < 0$

razryadlanish

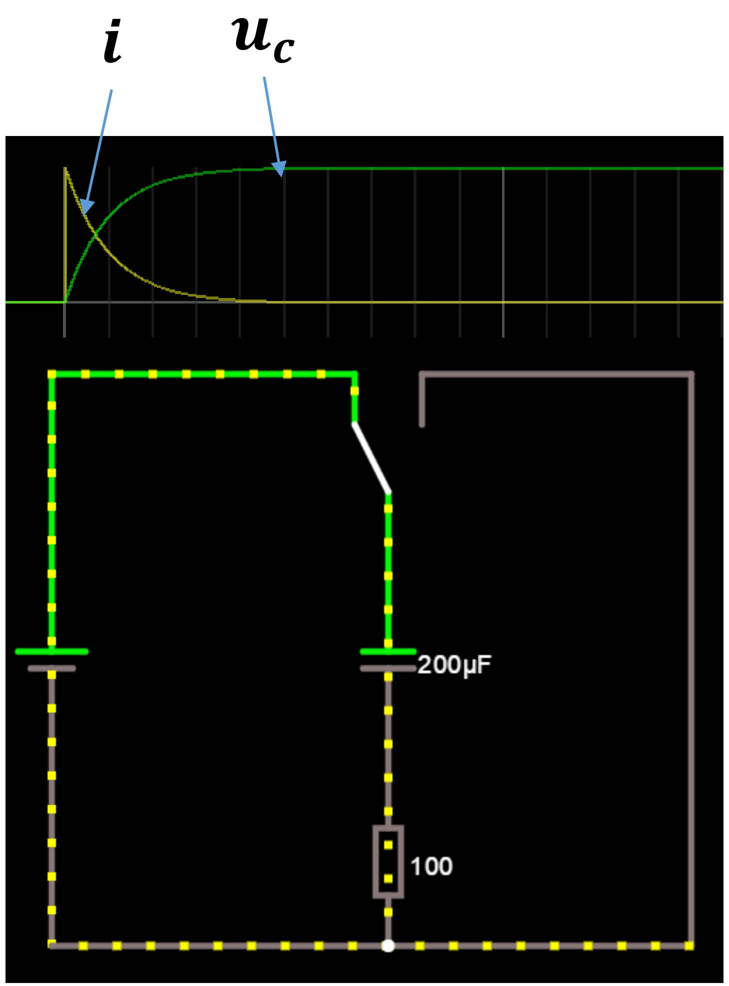


Photo source: [8] - Circuit_Simulator_1.2.0_x64_setup program. (Capacitor_Discharge)

Photo source: [6] - https://myelectrical.com/Portals/0/SunBlogNuke/2/WindowsLiveWriter/CapacitorTheory_C3D4/capacitorVoltageCurrent_thumb.jpg

Photo source: [7] - Circuit_Simulator_1.2.0_x64_setup program. (Capacitor_Charge)

Polister kondansatorlar yengil, barqaror va ularning harorat bilan o‘zgarishini oldindan aytish mumkin.

Polister o‘rniga slyuda va polistirol kabi boshqa dielektrik materiallardan foydalanish mumkin.

Kondensator qog‘ozi metall yoki plastmassa plyonkalarga o‘rab joylashtiriladi.

Elektrolitik kondensatorlar juda yuqori sig‘im hosil qiladi.

a) b) c)

6.4-rasm. Kondensatorlar.

a) polister kondensator, b) keramik kondensator, c) elektrolitik kondansator.

Photo source: [9] - Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 218.

Trimmer (*yoki padder*) kondensatorining sig‘imi ko‘pincha boshqa kondensator bilan parallel ravishda joylashtiriladi, shuning uchun ekvivalent sig‘im biroz o‘zgarishi mumkin.

O‘zgaruvchan havo kondensatorining (*to‘rli plitalar*) sig‘imi milni aylantirish orqali o‘zgaradi.

a)

b)

Photo source: [10] - https://www.surplussales.com/Images/Capacitors/PistonTrimmers/ctp-47283_thumb.png

6.5-rasm. O‘zgaruvchan kondensatorlar.

a) trimmer kondensator, b) plyonkali kondensator.

Photo source: [11] - https://www.surplussales.com/Images/Capacitors/PistonTrimmers/ctp-5601_thumb.png

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Kondensatorning tok kuchi va kuchlanish munosabatini olish uchun (6.1) tenglamaning ikkala tomonining hosilasini olamiz:

$$i = \frac{dq}{dt} \qquad (6.3)$$

(6.1) tenglamaning ikkala tomonini farqlaymiz:

$$\boldsymbol{q = Cu} \qquad i = C\frac{du}{dt} \qquad (6.4)$$

Bu passiv belgi konventsiyasini qabul qilgan holda, kondensator uchun tok kuchi va kuchlanish munosabatidir.

(6.4) tenglama bo‘yicha kondensator tok o‘tkazishi uchun uning kuchlanishi vaqt o‘tishi bilan o‘zgarishi kerak. Demak, o‘zgarmas kuchlanish uchun $i = 0$.

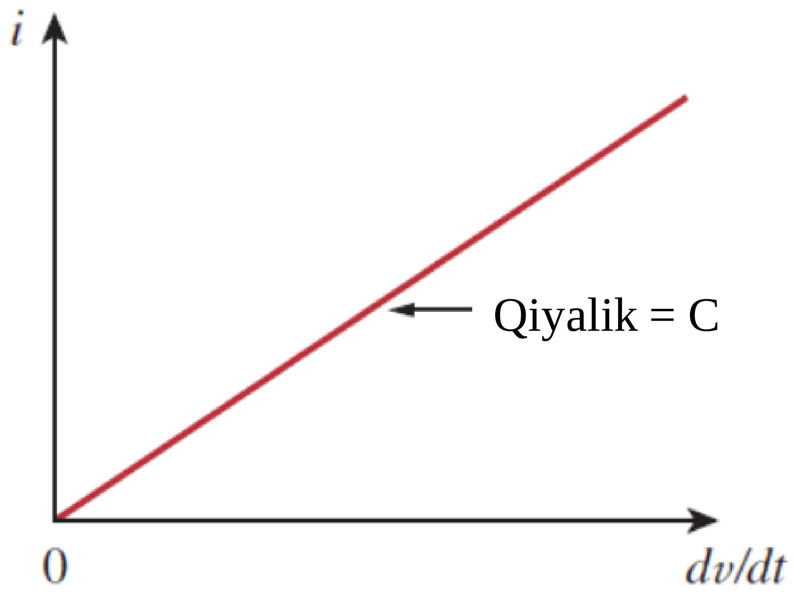
(6.4) tenglamaning har ikkala tomonini integrallash orqali kondensatorning tok kuchi va kuchlanish munosabatini olishimiz mumkin.

$$u(t) = \frac{1}{C}\int_{-\infty}^{t} i(\tau)d\tau \qquad (6.5)$$

yoki,

$$u(t) = \frac{1}{C}\int_{-\infty}^{t} i(\tau)d\tau + u(t_o) \qquad (6.6)$$

bu yerda: $u(t_o) = \frac{q(t_o)}{C}$, t_o vaqtidagi kondensator kuchlanishi.



6.6-rasm. Kondensatorning tok kuchi va kuchlanish munosabati.

Kondensatorga beriladigan oniy quvvat:

$$p = ui = Cu\frac{du}{dt} \tag{6.7}$$

Shunday qilib, kondensatorda saqlanadigan energiya:

$$W = \int_{-\infty}^{t} p(\tau)d\tau = C\int_{-\infty}^{t} u\frac{du}{dt}d\tau = C\int_{u(-\infty)}^{u(t)} udu = \frac{1}{2}Cu^2\Big|_{u(-\infty)}^{u(t)} \tag{6.8}$$

Biz $u(-\infty) = 0$ ekanligini ta'kidlaymiz, chunki kondensator $t = -\infty$ da zaryadsizlangan. Shunday qilib,

$$\boxed{W = \frac{1}{2}Cu^2} \tag{6.9}$$

(6.1) tenglamadan foydalanib, (4.9) tenglamani qayta yozishimiz mumkin.

$$W = \frac{q^2}{2C} \tag{6.10}$$

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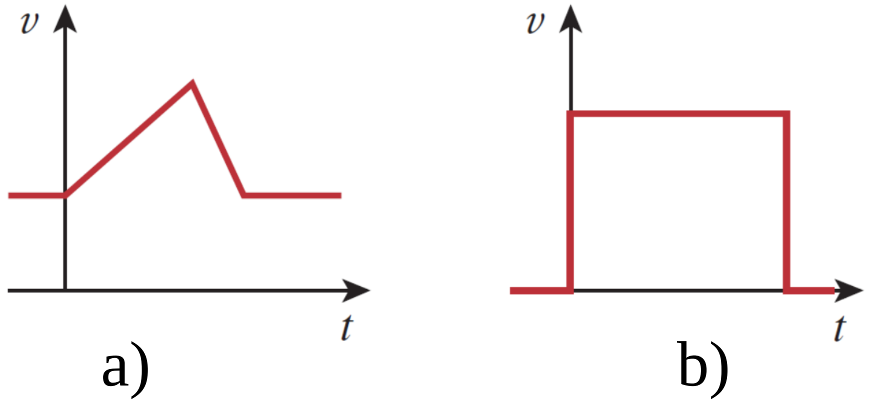
Kondensatorning quyidagi muhim xususiyatlariga e'tibor qaratishimiz kerak:

1. Kondensatordagi kuchlanish vaqt o‘tishi bilan o‘zgarmasa, kondensator orqali o‘tayotgan tok kuchi nolga teng bo‘ladi. Kondensator o‘zgarmas tok kuchi sharoitida uzoq ishlagandan so‘ng ochiq zanjirni hosil qiladi. Agar batareya kondensator orqali ulangan bo‘lsa, kondansator zaryadlanadi.

2. Kondensatordagi kuchlanish uzluksiz bo‘lishi kerak.

Kondensatordagi kuchlanish keskin o‘zgarishi mumkin emas.



6.7-rasm. Kondensatordagi kuchlanish.
a) ruxsat etilgan; b) ruxsat etilmagan, keskin o‘zgarish mumkin emas.

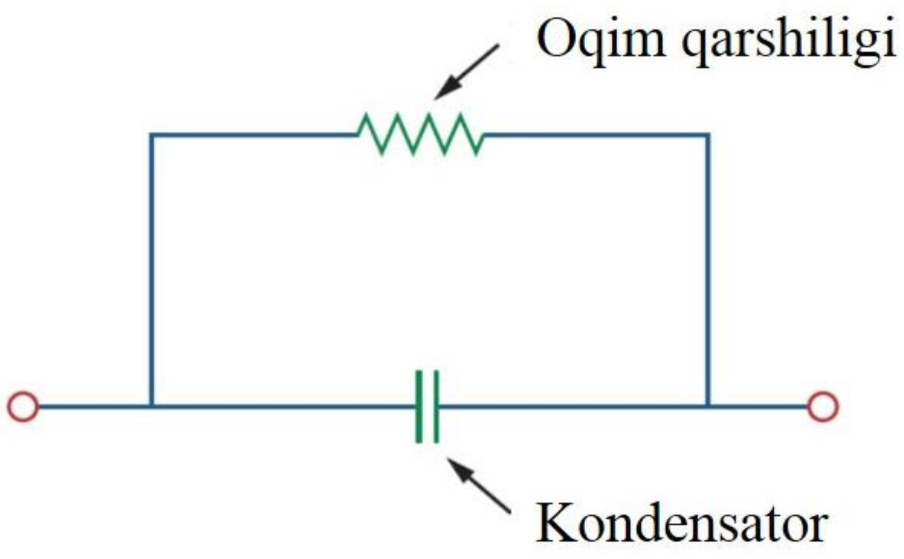
Kondensator uning ustidagi kuchlanishning keskin o‘zgarishiga qarshilik ko‘rsatadi.

$$\boldsymbol{i = C\frac{du}{dt}}$$

(6.4) tenglama bo‘yicha kuchlanishning uzluksiz o‘zgarishi cheksiz tok kuchini talab qiladi, bu jismoniy jihatdan mumkin emas.

3. Ideal kondensator energiyani yutmaydi. U o‘z maydonida energiyani to‘plashda zanjirdagi quvvatni oladi va zanjirga ilgari saqlangan energiyani qaytaradi.

4. Haqiqiy, ideal bo‘lmagan kondensator 6.8-rasmda ko‘rsatilgan. Parallel modeldagi oqimning qarshiligi 100 MΩ gacha bo‘lishi mumkin.



6.8-rasm. Ideal bo‘lmagan kondensatorning elektr zanjir modeli.

6.1.1-masala: a) 20 V bo‘lgan 3 pF kondensatorda saqlangan zaryadni hisoblang.

b) Kondensatorda to‘plangan energiyani toping.

Yechish:

a) $q = Cu$ ekanligidan foydalanib,

$$q = 3 \cdot 10^{-12} \cdot 20 = 60\ pC$$

b) Saqlangan energiya,

$$W = \frac{1}{2} Cu^2 = \frac{1}{2} \cdot 3 \cdot 10^{-12} \cdot 400 = 600\ pJ$$

6.1.2-masala: 5μF kondensatordan o‘tuvchi kuchlanish $u(t) = 10\cos 6000t\ V$

U yerdan o‘tuvchi tok kuchini toping.

Yechish:

Ta’rifga ko‘ra, tok kuchi:

$$i = C\frac{du}{dt} = 5 \cdot 10^{-6} \frac{d}{dt}(10\cos 6000\ t) =$$

$$= -5 \cdot 10^{-6} \cdot 6000 \cdot 10\sin 6000\ t =$$

$$= -0{,}3\sin 6000\ t\ A$$

Izoh: cos ni hosilasi (-*sin*) ga teng.

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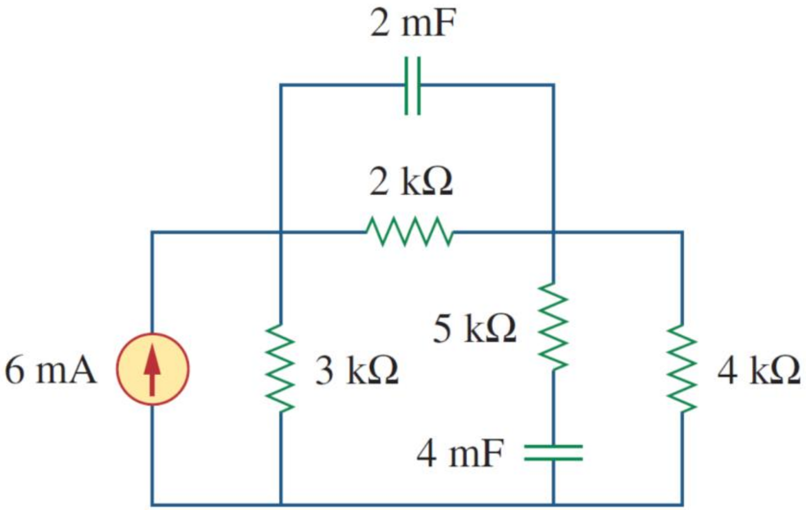
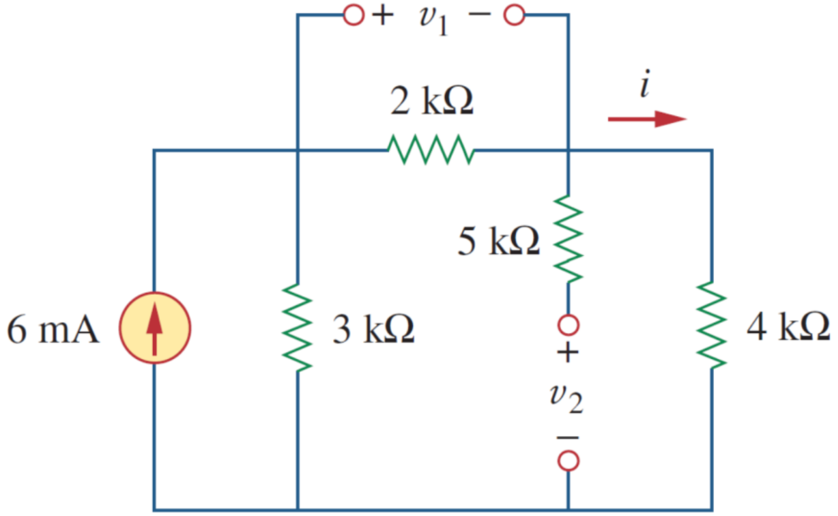
6.1.3-masala. Har bir kondensatorda oʻzgarmas tok sharoitida saqlanadigan energiyani hisoblang.





Yechish:

$$i = \frac{3}{3+2+4}(6\text{ mA}) = 2\text{ mA}$$

$$v_1 = 2000i = 4\text{ V}$$

$$v_2 = 4000i = 8\text{ V}$$

$$w_1 = \frac{1}{2}C_1v_1^2 = \frac{1}{2}(2\times 10^{-3})(4)^2 = 16\text{ mJ}$$

$$w_2 = \frac{1}{2}C_2v_2^2 = \frac{1}{2}(4\times 10^{-3})(8)^2 = 128\text{ mJ}$$

6.2. Ketma-ket va parallel ulangan kondensatorlar.

Rezistorli zanjirlarda ketma-ket va parallel ulanishlar zanjirlarni qisqartirish uchun kuchli vositadir.

Ushbu usuldan kondensatorlarni ham ketma-ket va parallel ulash uchun qo‘llash mumkin.

6.9-a, rasmda KCL ni qo‘llaymiz:

$$\boldsymbol{i = i_1 + i_2 + i_3 + \cdots + i_N} \qquad (6.11)$$

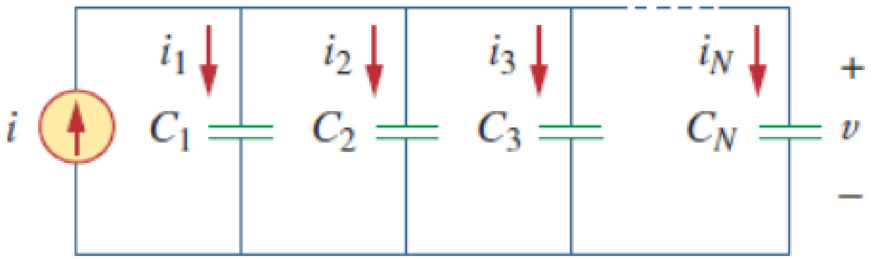
Lekin, $i_k = C_k \frac{du}{dt}$ demak,

$$i = C_1 \frac{du}{dt} + C_2 \frac{du}{dt} + C_3 \frac{du}{dt} + \cdots$$

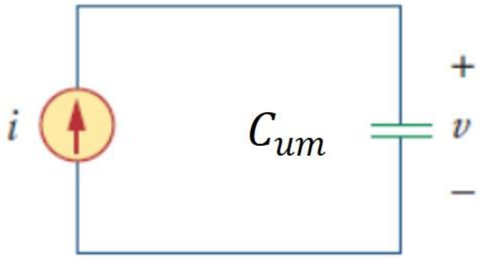
$$+ C_N \frac{du}{dt} = \left(\sum_{k=1}^{N} C_k\right) \frac{du}{dt} = C_{um} \frac{du}{dt} \qquad (6.12)$$

bu yerda:

$$\boldsymbol{C_{um} = C_1 + C_2 + C_3 + \cdots + C_N} \qquad (6.13)$$



a)



b)

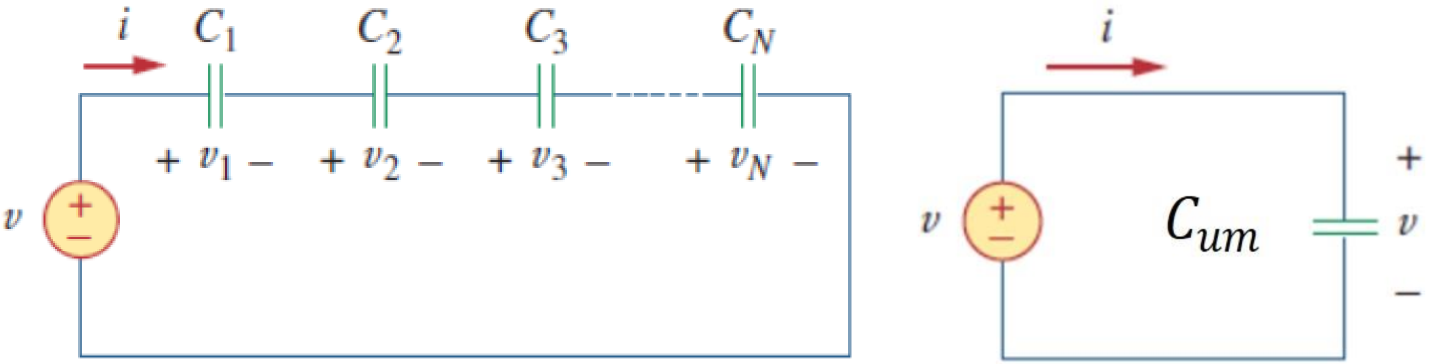
6.9-rasm.
a) N ta kondensatorlarning parallel ulanishi;
b) Parallel kondensatorlar uchun ekvivalent zanjiri.

Bir xil tok kuchi i kondensatorlar orqali oqadi (*va shunga mos ravishda bir xil zaryad ham*).

6.10-a rasmdagi halqaga KVLni qo‘llaymiz: $$\boldsymbol{u = u_1 + u_2 + u_3 + \cdots + u_N} \qquad (6.14)$$

Lekin, $u_k = \frac{1}{C_k}\int_{t_0}^{t} i(\tau)d\tau + u_k(t_0)$. Shuning uchun,

$$u = \frac{1}{C_1}\int_{t_0}^{t} i(\tau)d\tau + u_1(t_0) + \frac{1}{C_2}\int_{t_0}^{t} i(\tau)d\tau + u_2(t_0) + \dots + \frac{1}{C_N}\int_{t_0}^{t} i(\tau)d\tau + u_N(t_0) = \left(\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}\right)\int_{t_0}^{t} i(\tau)d\tau + u_1(t_0) + u_2(t_0) + \cdots + u_N(t_0) = \frac{1}{C_{um}}\int_{t_0}^{t} i(\tau)d\tau + u(t_0) \qquad (6.15)$$



a) b)

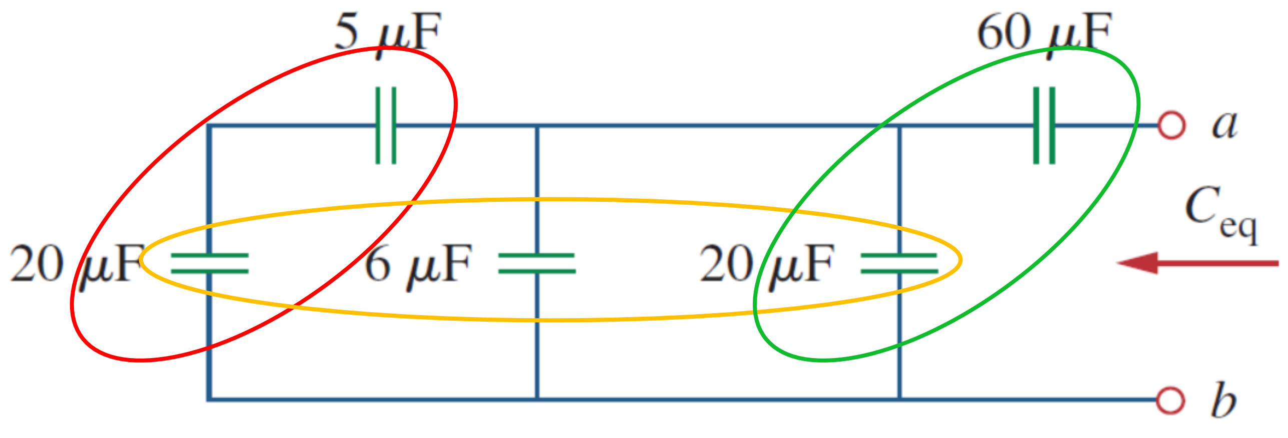
6.10-rasm.

a) N ta kondensatorlarning ketma-ket ulanishi;
b) Ketma-ket kondensatorlar uchun ekvivalent zanjiri.

bu yerda:

$$\boldsymbol{\frac{1}{C_{um}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}} \qquad (6.16)$$

6.2.1-masala: 6.11-rasmdagi zanjirning *a*-*b* terminallari orasidagi ekvivalent sig‘imni toping.



6.11-rasm.

Yechish:

$$\frac{20\cdot 5}{20+5}=4\ \mu F$$

$$4+6+20=30\ \mu F$$

$$C_{um}=\frac{30\cdot 60}{30+60}=20\ \mu F$$

Ketma-ket ulangan kondensator:

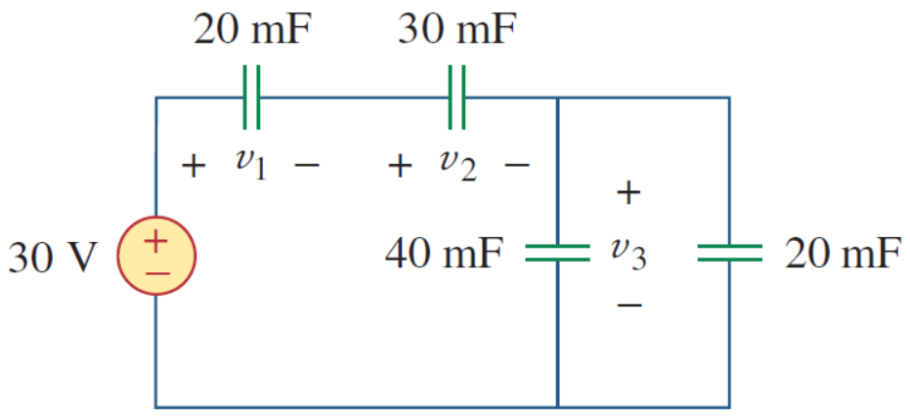
$$\frac{1}{C_{um}}=\frac{1}{C_1}+\frac{1}{C_2}\quad \text{yoki,}\quad C_{um}=\frac{C_1C_2}{C_1+C_2}$$

Parallel ulangan kondensator:

$$C_{um}=C_1+C_2+C_3+\cdots+C_N$$

$$C_{um}=((20||5)+6+20)||60=20\ \mu F$$

6.2.2-masala: 6.12-rasmdagi zanjirning har bir kondensatoridan oʻtuvchi kuchlanishini toping.

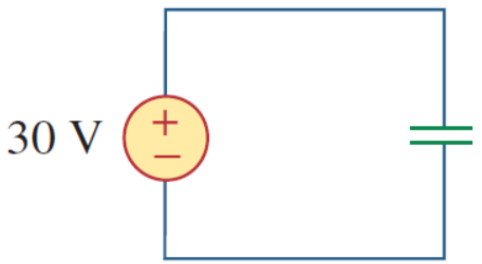


6.12-rasm.

Yechish:

$$40 + 20 = 60\ \mu F$$

$$C_{um} = \frac{1}{\frac{1}{60} + \frac{1}{30} + \frac{1}{20}} = 10\ \mu F$$



$$C_{um} = 10\ \mu F$$

$$q = C_{um}u = 10 \cdot 10^{-3} \cdot 30 = 0{,}3\ C$$

$$u_1 = \frac{q}{C_1} = \frac{0{,}3}{20 \cdot 10^{-3}} = 15\ V \qquad u_2 = \frac{q}{C_2} = \frac{0{,}3}{30 \cdot 10^{-3}} = 10\ V$$

$$u_3 = 30 - U_1 - U_2 = 5\ V$$

$$u_3 = \frac{q}{60\ \mu F} = \frac{0{,}3}{60 \cdot 10^{-3}} = 5\ V$$

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