9-Mavzu: O‘zgaruvchan tok zanjiri. Sinusoidlar va fazalar *(davomi)*.

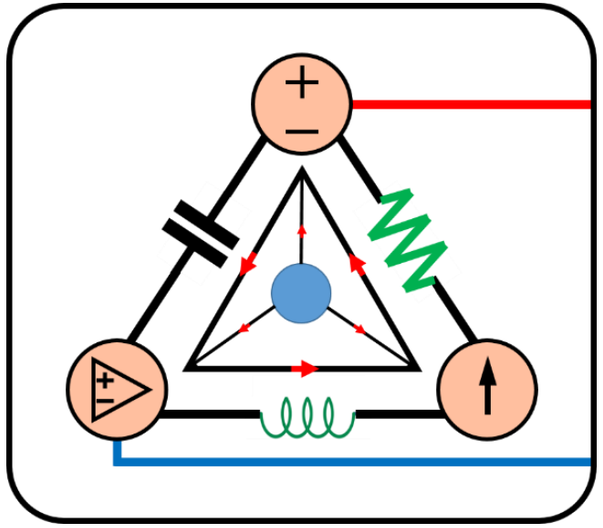
(9th Topic: AC Circuit. Sinusoids and Phasors.)

9-Mavzuning 4-qismi

(4th part of the 9th Topic)

12-hafta uchun

For the 12th week



Lecturer: Ph.D., Yusupov Sarvarbek

Toshkent Kimyo Xalqaro Universiteti
“Mashinasozlik texnologiyasi” kafedrasi
Toshkent shahri, Usmon Nosir, 156-uy.

9-Mavzu: O‘zgaruvchan tok zanjiri. Sinusoidlar va fazalar *(davomi)*.

(9th Topic: AC Circuit. Sinusoids and Phasors.)

O‘quv rejasi:

9.5. Qarshilik va o‘tkazuvchanlik (impidance and admittance).

9.6. Chastotalar sohasida Kirxgof qonunlari.

9.7. Qarshilik kombinatsiyalari.

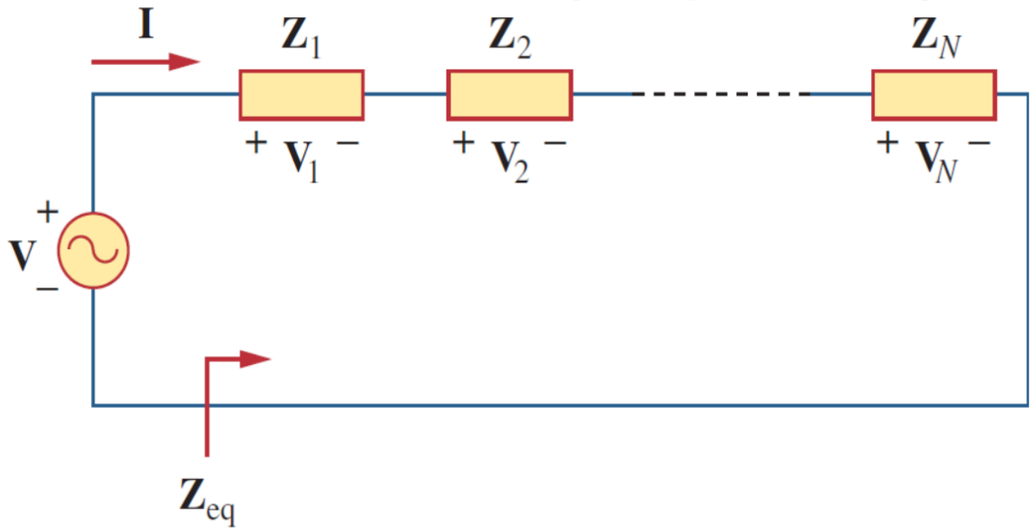
9.8. Qo‘llanilishi.

9.7. Qarshilik kombinatsiyalari.

N ta ketma-ket ulangan impidenslarni ko‘rib chiqaylik. Xuddi shu tok kuchi ***I*** impidenslar orqali oqadi. Kontur bo‘ylab KVLni qo‘llaymiz.

$$U = U_1 + U_2 + \cdots + U_N = I(Z_1 + Z_2 + \cdots + Z_N) \qquad (9.58)$$

Kirish terminalidagi impidensning ekvivalenti quyidagicha aniqlanadi.



9.17-rasm. Ketma-ket ulangan *N* ta impidenslar.

Photo source: [18] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 390.

$$Z_{um} = Z_{eq} = \frac{U}{I} = Z_1 + Z_2 + \cdots + Z_N$$

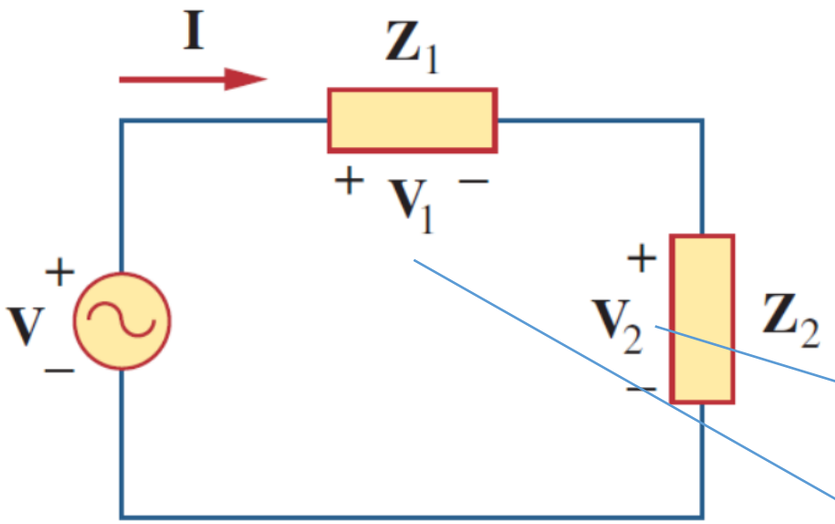
yoki,

$$Z_{um} = Z_1 + Z_2 + \cdots + Z_N \qquad (9.59)$$

ketma-ket bog‘langan impidenslarning umumiy yoki ekvivalent impidensi individual impidenslarning yig‘indisi ekanligini ko‘rsatadi.

Bu qarshiliklarning ketma-ket ulanishiga o‘xshaydi.

N=2 bo‘lsa, impedanslar orqali to kuchi quyidagicha hisoblanadi.



9.18-rasm. Kuchlanishni bo‘linishi.

$$I = \frac{U}{Z_1+Z_2} \qquad (9.60)$$

Shunday qilib, $U_1 = Z_1 I$ va $U_2 = Z_2 I$, u holda kuchlanishni bo‘linish qoidasi quyidagicha yoziladi.

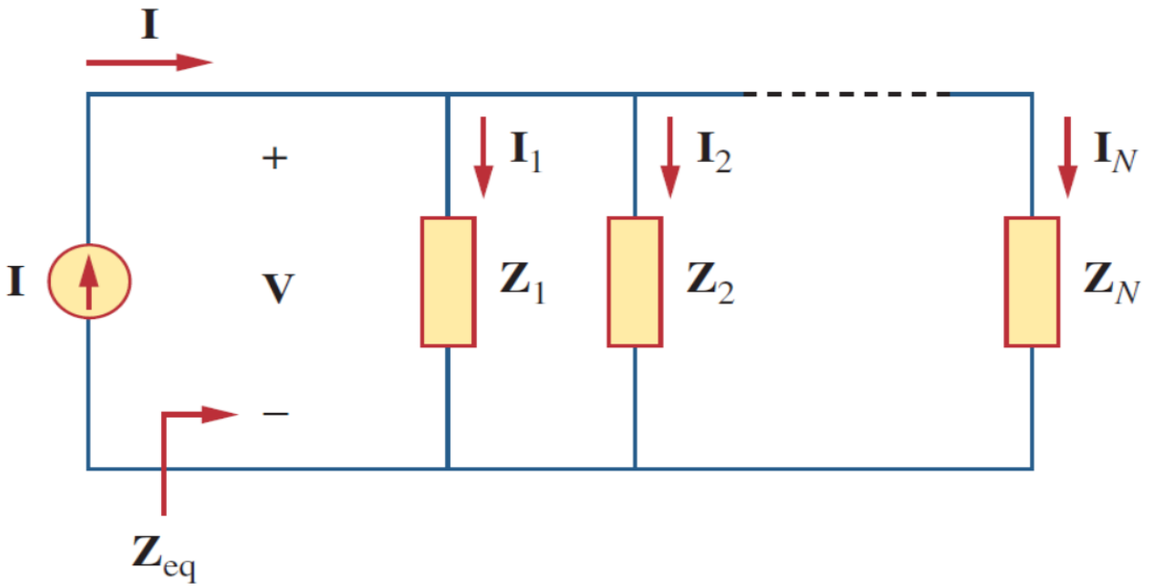
$$U_1 = \frac{Z_1}{Z_1+Z_2} U; \qquad U_2 = \frac{Z_2}{Z_1+Z_2} U. \qquad (9.61)$$

Photo source: [19] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 391.

N ta parallel ulangan impidensning ekvivalent impidensini olishimiz mumkin.

Har bir impidensdagi kuchlanish bir xil.

Tugunda KCL ni qo‘llaymiz, $$\boldsymbol{I = I_1 + I_2 + \cdots + I_N = U\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \cdots + \frac{1}{Z_N}\right)} \qquad (9.62)$$



9.19-rasm. Parallel ulangan *N* ta impidenslar.

Kirish terminalidagi impidensning ekvivalenti quyidagicha aniqlanadi.

$$\boldsymbol{\frac{1}{Z_{um}} = \frac{1}{Z_{eq}} = \frac{I}{U} = \frac{1}{Z_1} + \frac{1}{Z_2} + \cdots + \frac{1}{Z_N}} \qquad (9.63)$$

Ekvivalent admittensi esa,

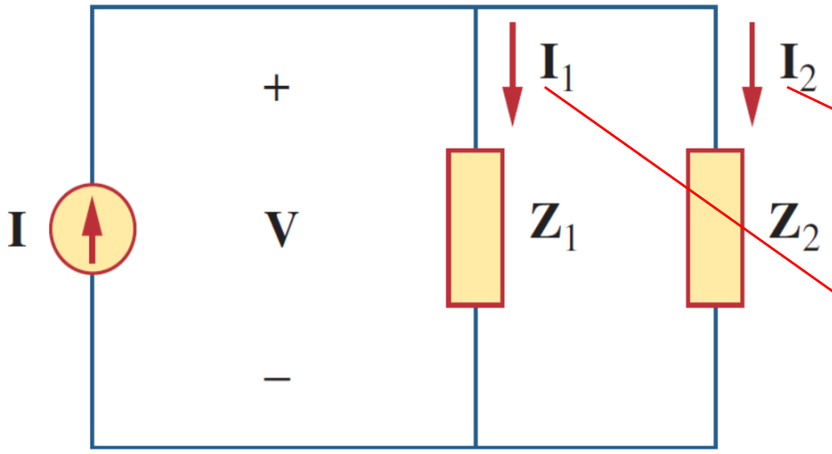
$$\boldsymbol{Y_{um} = Y_{eq} = Y_1 + Y_2 + \cdots + Y_N} \qquad (9.64)$$

Photo source: [19] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 391.

N=2 bo‘lsa, ekvivalent impidens aylanadi.

$$Z_{um} = \frac{1}{Y_{um}} = \frac{1}{Y_1+Y_2} = \frac{1}{\frac{1}{Z_1}+\frac{1}{Z_2}} = \frac{Z_1 Z_2}{Z_1+Z_2} \qquad (9.65)$$

Shunday qilib, $U = Z_{um} I = I_1 Z_1 = I_2 Z_2$



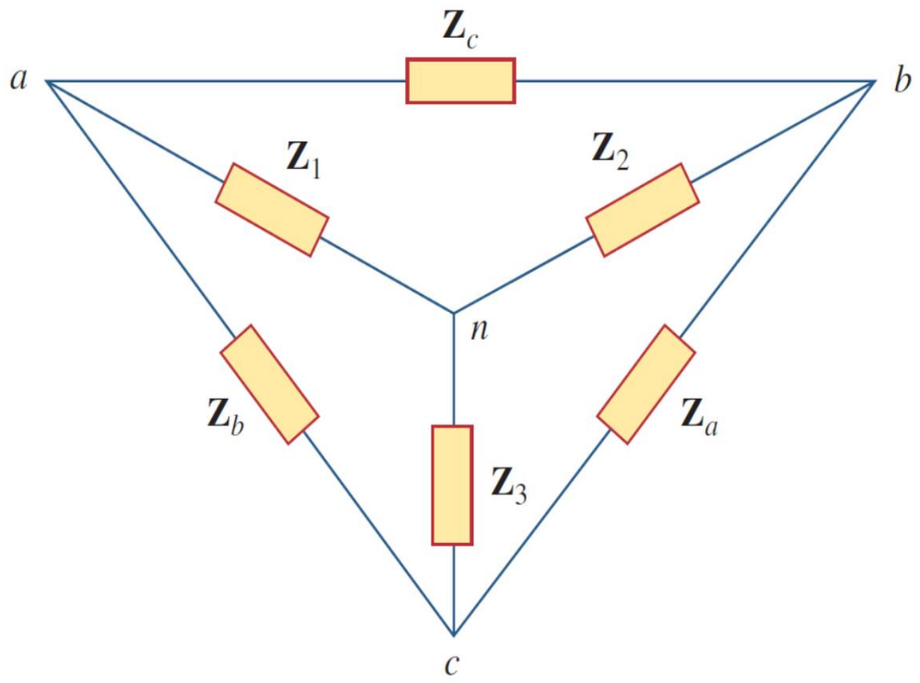
9.20-rasm. Tok kuchini bo‘linishi.

Photo source: [19] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 391.

Impidenslardagi tok kuchilarining bo‘linish qoidasi quyidagicha yoziladi.

$$I_1 = \frac{Z_2}{Z_1 + Z_2} I \qquad I_2 = \frac{Z_1}{Z_1 + Z_2} I \qquad (9.66)$$

Rezistorli zanjirlarga qo‘llagan delta-to-wye va wye-to-delta transformatsiyalari impidenslar uchun ham amal qiladi.



9.21-rasm. Y va Δ qatlamli tarmoqlar.

Photo source: [20] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 392.

Y – Δ konvertatsiyasi:

$$Z_a = \frac{Z_1Z_2 + Z_2Z_3 + Z_3Z_1}{Z_1}$$
$$Z_b = \frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_2} \qquad (9.67)$$
$$Z_c = \frac{Z_1Z_2 + Z_2Z_3 + Z_3Z_1}{Z_3}$$

Δ – Y konvertatsiyasi:

$$Z_1 = \frac{Z_bZ_c}{Z_a + Z_b + Z_c}$$
$$Z_2 = \frac{Z_cZ_a}{Z_a+Z_b+Z_c} \qquad (9.68)$$
$$Z_3 = \frac{Z_aZ_b}{Z_a + Z_b + Z_c}$$

Δ yoki Y zanjiri, agar u uchta tarmoqda teng impidenslarga ega bo‘lsa, muvozanatli deyiladi.

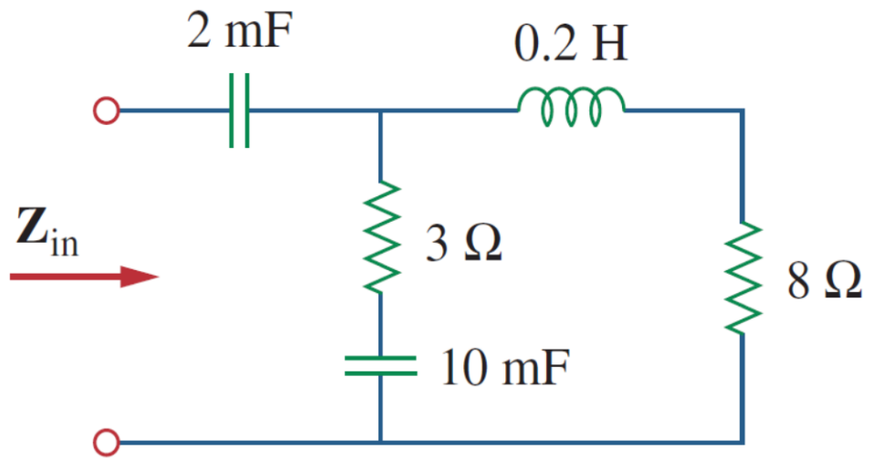
Δ - Y zanjir muvozanatlanganda (9.67) va (9.68) tenglamalar quyidagicha bo‘ladi.

$$Z_\Delta = 3Z_Y \quad \text{yoki,} \quad Z_Y = \frac{1}{3}Z_\Delta \tag{9.69}$$

bu yerda: $Z_Y = Z_1 = Z_2 = Z_3$ va $Z_\Delta = Z_a = Z_b = Z_c$.

O‘zgaruvchan tok zanjirlari uchun kuchlanishni bo‘linishi, tok kuchini bo‘linishi, zanjirni qisqartirish, impidens ekvivalenti va transformatsiya tamoyillari tahlil qilindi.

9.7.1-masala: 9.22-rasmdagi zanjirning kirish impidensini toping. Faraz qilaylik, zanjir $\omega = 50\ rad/s$ da ishlaydi.



9.22-rasm.

Yechish: Zanjir elementlarini chastota sohasiga o‘tkazib olamiz.

$$Z_1 = \frac{1}{j\omega C} = \frac{1}{j50 \cdot 2 \cdot 10^{-3}} = -j10\ \Omega$$

$$Z_2 = 3 + \frac{1}{j\omega C} = 3 + \frac{1}{j50 \cdot 10 \cdot 10^{-3}} = (3 - j2)\ \Omega$$

$$Z_3 = 8 + j\omega L = 8 + j50 \cdot 0{,}2 = (8 + j10)\ \Omega$$

Kiruvchi impidens,

$$Z_{in} = Z_1 + Z_2||Z_3 = -j10 + \frac{(3 - j2)(8 + j10)}{11 + j8} = -j10 + \frac{(44 + j14)(11 - j8)}{11^2 + 8^2} = -j10 + 3{,}22 - j1{,}07\ \Omega$$

$$\boldsymbol{Z_{in} = 3,22 - j11,07\ \Omega}$$

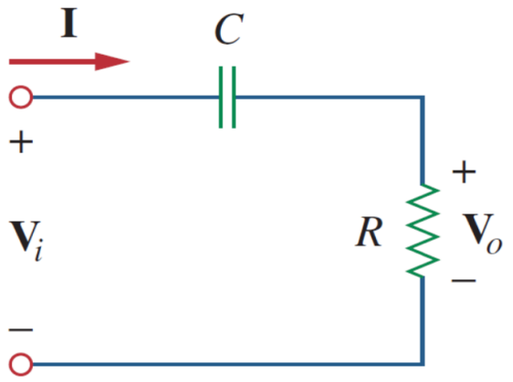
9.8. Qo‘llanilishi.

O‘zgarmas tok sharoitlarida *RC*, *RL* va *RLC* zanjirlaridan foydalanishni ko‘rib chiqdik. Bu zanjirlar ham o‘zgaruvchan toklarda ishlatiladi.

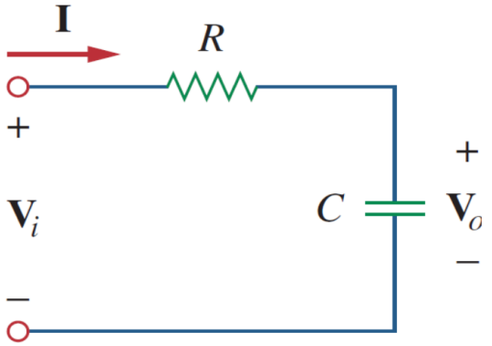
Ularning o‘zaro ulanish tartiblari, fazani o‘zgartirish zanjirlari, filtrlar, rezonans zanjirlar, o‘zgaruvchan tok ko‘prigi zanjirlari va transformatorlarda mavjud hisoblanadi.

Quyida ikkita holatlarni ko‘rib chiqamiz:

- *RC* fazasini o‘zgartirish zanjirlari;
- O‘zgaruvchan tok ko‘prigi zanjirlari.



a) yetakchi chiqish;



b) ortda qoladigan chiqish.

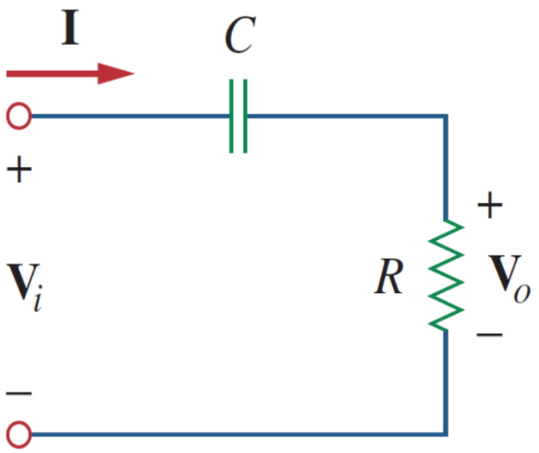
9.23-rasm. Ketma-ket ulangan RC faza o‘zgartirgich zanjiri:

Photo source: [21] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 396.

Fazani o‘zgartirish zanjiri ko‘pincha zanjirga kiruvchi faza almashinuvini tuzatish yoki maxsus kerakli effektlarni yaratish uchun ishlatiladi.

RC zanjiri bu maqsad uchun mos keladi, chunki uning sig‘imi qo‘llaniladigan kuchlanishni zanjir tok kuchiga olib keladi.

Ikkita ko‘p ishlatiladigan RC zanjiri 9.22-rasmda ko‘rsatilgan (*RL zanjirlari yoki har qanday reaktiv zanjirlar ham xuddi shu maqsadga xizmat qilishi mumkin*).



a) yetakchi chiqish;

zanjirdagi tok kuchi $\boldsymbol{I}$ qo‘llaniladigan kuchlanish $\boldsymbol{U_{in}}$ ni ba’zi bir faza burchagi $\boldsymbol{\theta}$ bilan olib boradi, bu yerda $0 < \theta < 90°$, R va C qiymatlariga bog‘liq.

Agar $X_C = -1/\omega C$ bo‘lsa, u holda umumiy impidens $Z = R + jX_C$ bo‘ladi va fazaning siljishi quyidagicha hisoblanadi:

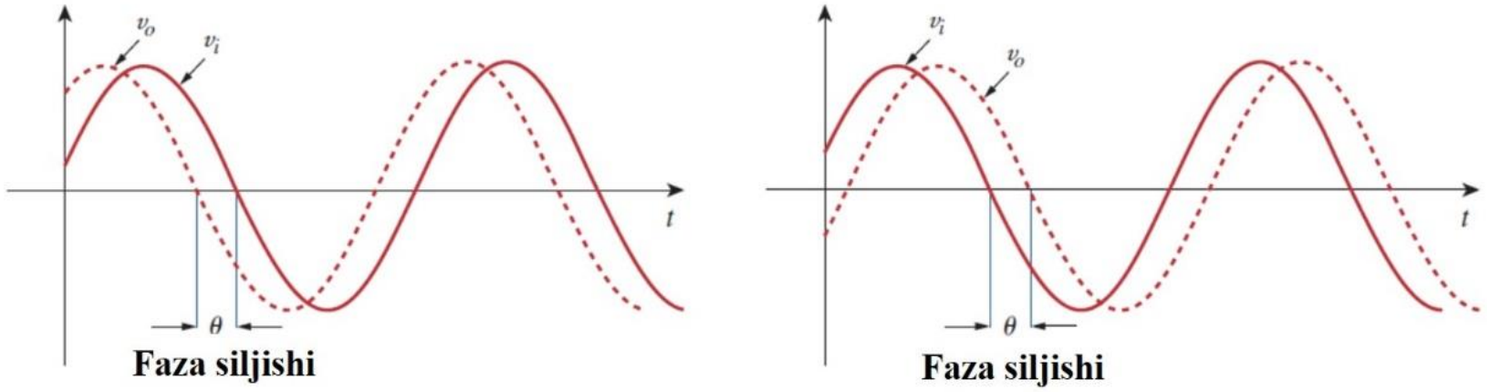
$$\boldsymbol{\theta = tan^{-1}\frac{X_C}{R}} \qquad (9.70)$$

Bu shuni ko‘rsatadiki, faza almashinuvi miqdori R, C va ish chastotasi qiymatlariga bog‘liq.

Rezistor bo‘ylab chiqish kuchlanishi $\boldsymbol{U_0}$ tok kuchi bilan fazada bo‘lgani uchun, 9.24-rasm, *a* da ko‘rsatilganidek, $\boldsymbol{U_0}$ $\boldsymbol{U_i}$ dan oldinda boradi (musbat faza siljishi).

9.24-rasm, *b* da chiqish kondensator bo‘ylab olinadi.

$\boldsymbol{I}\rightarrow$ $\boldsymbol{U_i}$ dan $\boldsymbol{\theta}$ ga oldinda boradi. $\boldsymbol{C}$ dagi $\boldsymbol{u_o(t)}$ $\boldsymbol{u_i(t)}$ dan kechikadi.

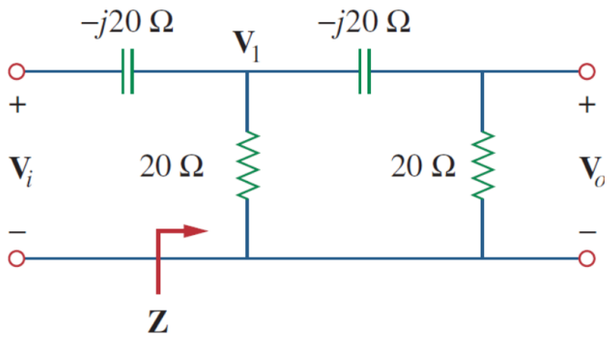


a) oldinga chiqish, b) kechikish bilan chiqish.

9.24-rasm. *RC* davrlarida faza siljishi.

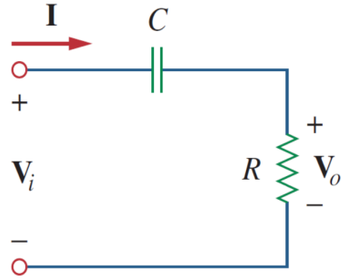
Photo source: [21] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 396.

9.8.1-masala: 90° yetakchi fazani ta’minlash uchun RC zanjirini loyihalang.

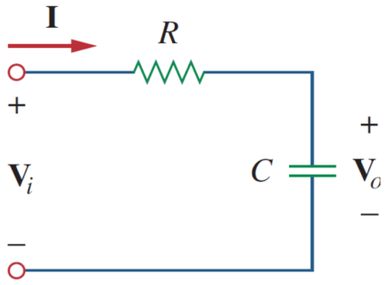


9.25-rasm.

Oldinda →



Ortda →



Yechish:

$$\boldsymbol{R = |X_C| = 20\ \Omega;}$$

$$\boldsymbol{\theta = tan^{-1}\frac{X_C}{R} \rightarrow \quad \theta = tan^{-1}1 \rightarrow \quad \theta = 45°}$$

$$Z = 20||(20 - j20) = \frac{20(20 - j20)}{40 - j20} = 12 - j4\ \Omega$$

Kuchlanishni bo‘linish qoidasi,

$$U_1 = \frac{Z}{Z - j20}U_i = \frac{12 - j4}{12 - j24}U_i = \frac{\sqrt{2}}{3}\angle 45°U_i \qquad (9.8.1)$$

va

$$U_0 = \frac{20}{20 - j20}U_i = \frac{\sqrt{2}}{3}\angle 45°U_i \qquad (9.8.2)$$

(9.8.1) tenglamani (9.8.2) tenglamaning hadlari o‘rniga qo‘yamiz.

$$U_0 = \left(\frac{\sqrt{2}}{3}\angle 45°\right)\left(\frac{\sqrt{2}}{3}\angle 45°U_i\right) = \frac{1}{3}\angle 90°U_i$$

Shunday qilib, chiqish kirishni 90° ga oldinda boradi, lekin uning kattaligi kirishning atigi 33 foizini tashkil qiladi.

9.8.2. AC ko‘priklar.

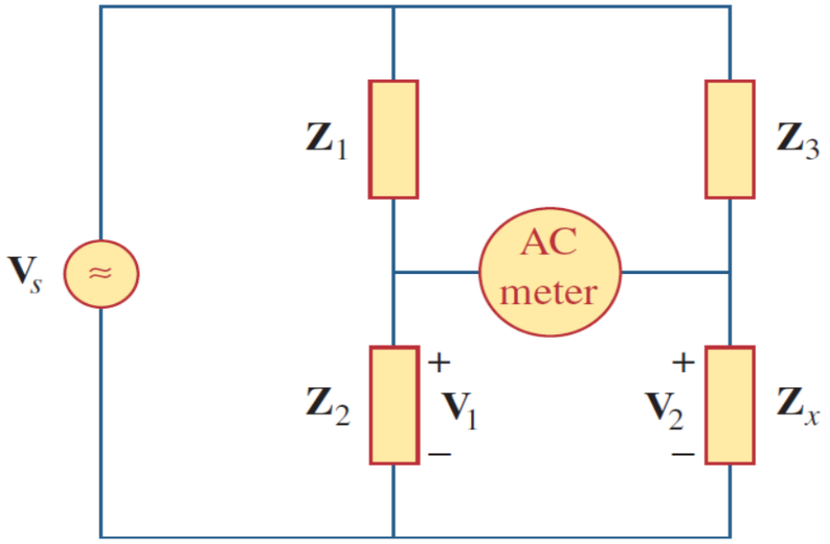
Induktor L ning induktivligini yoki kondansator C ning sig‘imini o‘lchashda o‘zgaruvchan tok ko‘prigi zanjiridan foydalaniladi.

U noma’lum qarshilikni o‘lchash uchun Wheatstone ko‘prigiga o‘xshash va xuddi shu prinsipga amal qiladi.

L va C ni o‘lchash uchun galvanometr o‘rniga o‘zgaruvchan tok manbai va o‘zgaruvchan tok o‘lchagich kerak bo‘ladi.

O‘zgaruvchan tok o‘lchagich sezgir o‘zgaruvchan tok ampermetri yoki voltmetr bo‘lishi mumkin.

9.26-rasmda ko‘rsatilgan umumiy o‘zgaruvchan tok ko‘prigi zanjirini ko‘rib chiqaylik. Hisoblagich orqali tok kuchi o‘tmasa, ko‘prik muvozanatlanadi. Bu shuni anglatadiki $U_1 = U_2$.



9.26-rasm. Umumiy o‘zgaruvchan tok ko‘prigi.

Kuchlanishni bo‘linish qoidasini qo‘llash,

$$U_1 = \frac{Z_2}{Z_1+Z_2}U_s = U_2 = \frac{Z_x}{Z_3+Z_x}U_s \qquad (9.71)$$

Demak,

$$\frac{Z_2}{Z_1+Z_2} = \frac{Z_x}{Z_3+Z_x} \rightarrow \quad Z_2Z_3 = Z_1Z_x \qquad (9.72)$$

yoki,

$$Z_x = \frac{Z_3}{Z_1}Z_2 \qquad (9.73)$$

Photo source: [22] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 399.

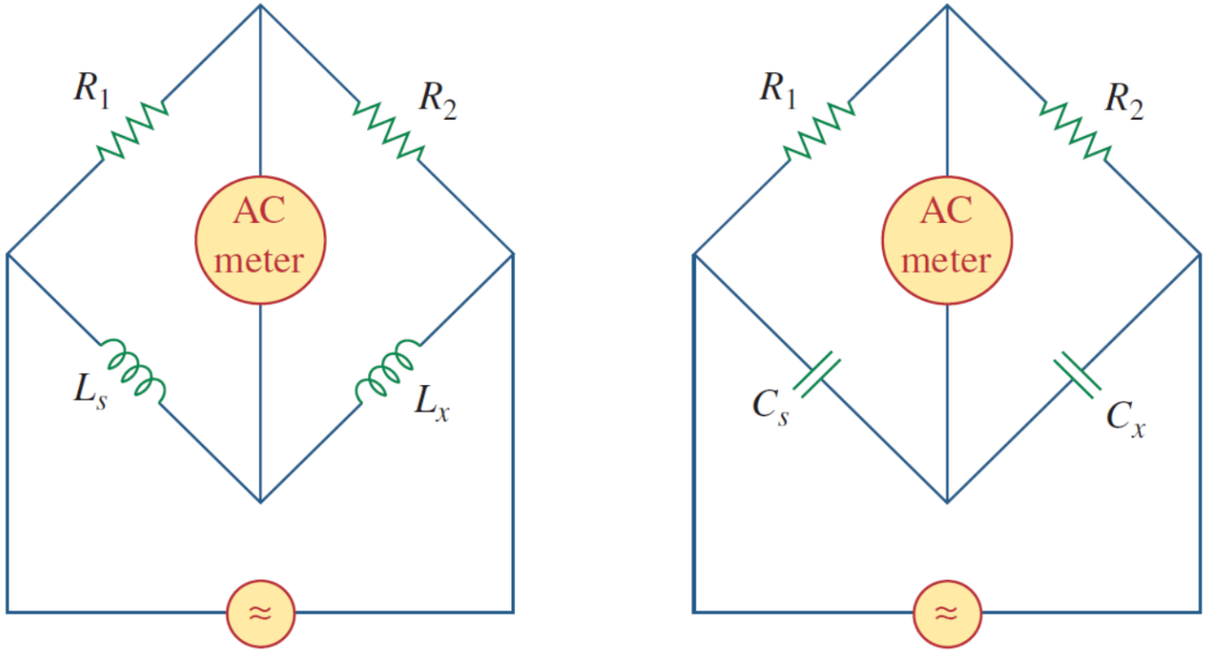
Bu o‘zgaruvchan tok ko‘prigi uchun muvozanatli tenglama bo‘lib, qarshilik ko‘prigi uchun tenglama (4.30) ga o‘xshaydi, bundan tashqari *R* lar *Z* bilan almashtiriladi.

$$\boldsymbol{R_x = \frac{R_3}{R_1} R_2} \qquad (4.30)$$

L va C ni o‘lchash uchun maxsus o‘zgaruvchan ko‘priklar 9.27-rasmda ko‘rsatilgan, bu yerda L_x va C_x o‘lchanadigan noma’lum indukiv va sig‘im, L_s va C_s esa standart induktiv va sig‘imdir (ularning qiymatlari katta aniqlik bilan ma’lum).

Har bir holatda, ikkita rezistor, R_1 va R_2 o‘zgaruvchan tok o‘lchagich nolga teng bo‘lguncha o‘zgaradi. Keyin ko‘prik muvozanatlanadi. (9.73) tenglamadan biz quyidagini olamiz.

$$\boldsymbol{L_x = \frac{R_2}{R_1} L_s} \qquad (9.74) \qquad \text{va} \qquad \boldsymbol{C_x = \frac{R_1}{R_2} L C_s} \qquad (9.75)$$



a) L o‘lchash uchun; b) C o‘lchash uchun.

9.27-rasm. Maxsus o‘zgaruvchan tok ko‘prigi:

9.27-rasmdagi o‘zgaruvchan tok ko‘priklarini muvozanatlash o‘zgaruvchan tok manbasining f chastotasiga bog‘liq emas, chunki f (9.74) va (9.75) tenglamalardagi munosabatlarda ko‘rinmaydi.

Photo source: [22] -Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 399.

FOYDALANILGAN MANBALAR:

18. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 390.
19. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 391.
20. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 392.
21. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 396.
22. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 399.

TEKSHIRISH UCHUN SAVOLLAR!

9.1. Quyidagilardan qaysi biri sinusoid $A\cos\omega t$ ni ifodalashning to‘g‘ri usuli emas?
A) $A\cos 2\pi\ ft.$ B) $A\cos(2\pi\ t/T).$
C) $A\cos\omega(t-T).$ D) $A\sin(\omega t-90°).$

9.2. Belgilangan oraliqlardan keyin takrorlanadigan funksiya deyiladi:
A) faza. B) garmonik. C) davriy. D) reaktiv.

9.3. Ushbu chastotalarning qaysi birining davri qisqaroq?
A) 1 krad/s. B) 1 kHz.

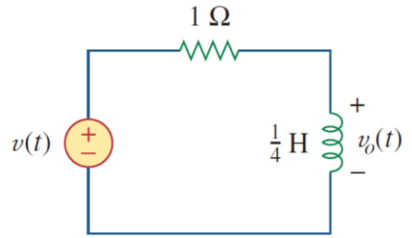
9.4. Agar $u_1=30\sin(\omega t+10°)$ va $u_2=20\sin(\omega t+50°)$ bo‘lsa, ushbu bayonotlarning qaysi biri to‘g‘ri?
A) u_1 u_2 dan oldinda. A) u_2 u_1 dan oldinda.
B) u_1 u_2 dan ortda. C) u_2 u_1 dan ortda.
D) $u_1$va u_2 fazada.

9.5. Induktordagi kuchlanish tok kuchini 90° ga olib boradi.
A) To‘g‘ri. B) Xato.

9.6 Impidansning hayoliy qismi deyiladi:
A) resistance. B) admittance.
C) susceptance. D) conductance. E) reactance.

9.7 Kondensatorning empedansi chastotaning ortishi bilan ortadi.
A) To‘g‘ri. B) Xato.

9.8. 9.28-rasmdagi chiqish kuchlanishi $u_0(t)$ qaysi chastotada kirish kuchlanishiga $u(t)$ teng bo‘ladi?
A) 0 rad/s. B) 1 rad/s. C) 4 rad/s.
D) rad/s. E) yuqoridagilarning hech biri.



9.28-rasm.

9.9. Ketma-ket RC zanjiri $|U_R|=12\ V$ va $|U_C|=5\ V$ ga ega. Ta’minot kuchlanishining kattaligi:
A) -7 V. B) 7 V. C) 13 V. D) 17 V.

9.10. Ketma-ket RCL zanjiri $R=30\ \Omega$, $X_C=50\ \Omega$ va $X_L=90\ \Omega$ ga ega. Zanjirning impidensi:
A) $30+j140\ \Omega.$ B) $30+j40\ \Omega.$
C) $30-j40\ \Omega.$ D) $-30-j40\ \Omega.$
E) $-30+j40\ \Omega.$

E'TIBORINGIZ UCHUN RAHMAT!!!