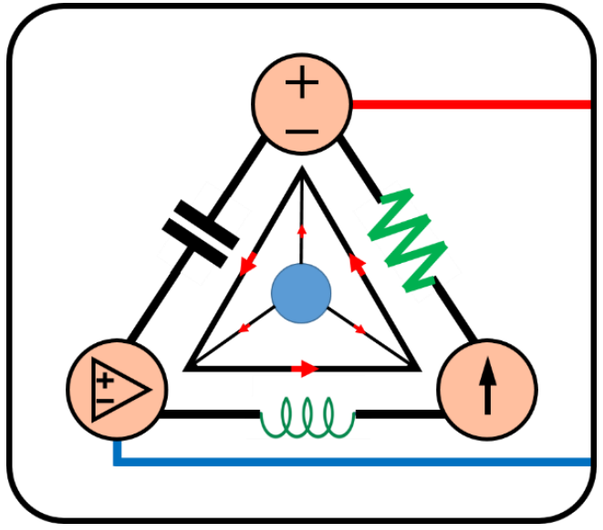
4-Mavzu: Elektr zanjir teoremalari.

(Lecture-4: Circuit Theorems)

4-Mavzuning 1-qismi

(Part 1 of the Lecture-4)



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4-Mavzu: Elektr zanjir teoremalari.

(Lecture-4: Circuit Theorems)

O‘quv rejasi:

4.1. O‘zgarmas elektr tok zanjirlarining chiziqli xossalari.

4.2. Superpozitsiya.

4.3. Manbani o‘zgartirish.

4.4. Tevenin teoremasi.

4.5. Norton teoremasi.

4.6. Maksimal quvvat uzatish.

4.7. Qo‘llanilishi.

4.1. O‘zgarmas elektr tok zanjirlarining chiziqli xossalari.

Chiziqli – bu sabab va natija o‘rtasidagi chiziqli munosabatni tavsiflovchi elementning xususiyati.

Misol uchun rezistor (R) uchun Om qonuniga muvofiq tok kuchi (I) kirishini va kuchlanish (U) chiqishi bilan ifodalanadi.

$$U = I \cdot R \tag{4.1}$$

Agar tok kuchi k miqdorda ortadigan bo‘lsa, kuchlanishning qiymati ham k miqdorda oshadi:

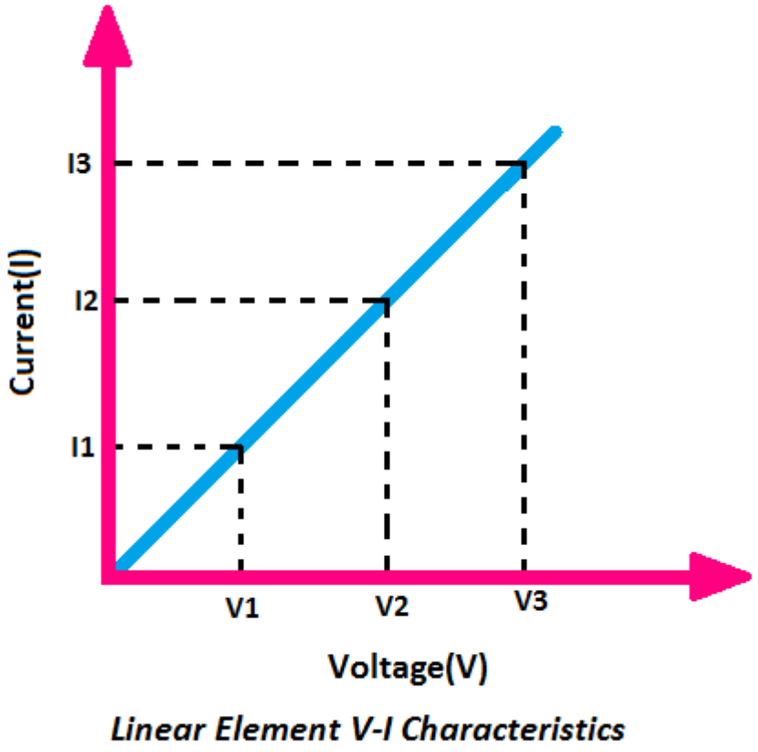
$$k \cdot I \cdot R = k \cdot U \tag{4.2}$$

Agar ikkita kiruvchi tok kuchi chiquvchi kuchlanishlardan hosil bo‘lsa,

$$U_1 = I_1 \cdot R \quad \text{va} \quad U_2 = I_2 \cdot R \tag{4.3}$$

Natijada umumiy tok kuchi $(I_1 + I_2)$ ni bilgan holda quyidagi ifodaga ega bo‘lamiz.

$$U = (I_1 + I_2)R = I_1 \cdot R + I_2 \cdot R = U_1 + U_2 \qquad (4.4)$$



Linear Element V-I Characteristics

Biz rezistorni chiziqli element deb ataymiz, chunki ***kuchlanish*** - ***tok kuchi*** munosabatlari bir xillikni ham, qo‘shilish xususiyatlarini ham qanoatlantiradi.

Chiziqli elektr zanjirda chiquvchi ko‘rsatkich uning kiruvchi ko‘rsatkichiga chiziqli bog‘liq (*yoki to‘g‘ridan-to‘g‘ri proporsional*) bo‘ladi.

Photo source: [1] - https://1.bp.blogspot.com/-OqYUMOc3iW8/YQZ1XZag4MI/AAAAAAAABVw/N0Cy2YwwGbEB96BmhvurgSt0rdmf4ojKwCLcBGAsYHQ/s434/Linear%2BElement%2BVI%2BCharacteristics.png

Chiziqli elektr zanjiri

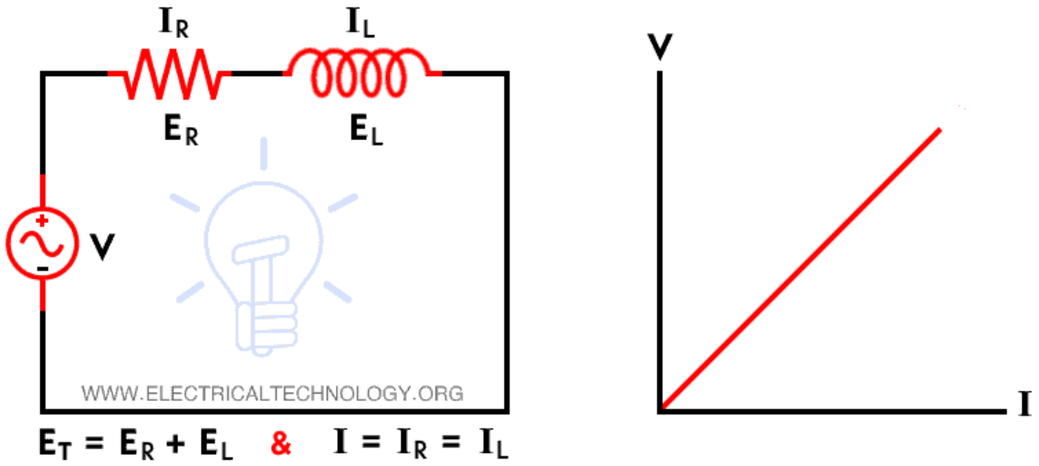


Photo source: [2] - https://www.electricaltechnology.org/wp-content/uploads/2013/12/Linear-Circuit-768x408.png

Chiziqli elektr zanjiri faqat chiziqli elementlardan, chiziqli bog‘liq manbalardan va mustaqil manbalardan iborat bo‘ladi.

No chiziqli elektr zanjiri

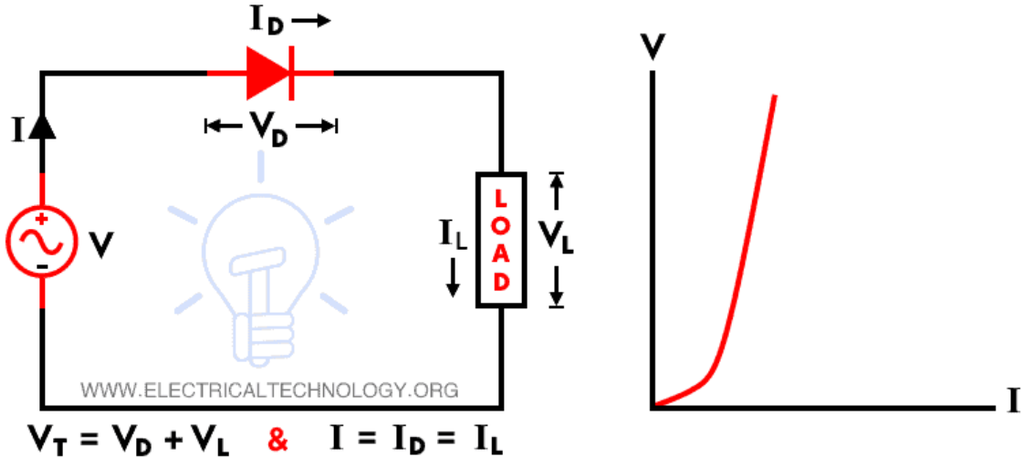


Photo source: [3] - https://www.electricaltechnology.org/wp-content/uploads/2013/12/Nonlinear-Circuit.png

Bu mavzuda faqat chiziqli elektr zanjirlarini ko‘rib chiqamiz. Chunki, $P = I^2R = U^2/R$ (uni chiziqli emas, kvadratik funksiyaga aylantiradi), quvvat va kuchlanish (yoki tok kuchi) o‘rtasidagi bog‘liqlik chiziqli emas.

Chiziqli elektr zanjirning ichida mustaqil manbalar yo‘q. **Kuchlanish manbai U_s** tomonidan kiruvchi sifatida xizmat qiladi. Elektr zanjiri qarshilik ***R*** yuklamasi bilan tugatiladi.

4.1-rasm. Kiruvchi $U_s$va chiquvchi *I* bo‘lgan chiziqli elektr zanjiri.

Chiqish sifatida ***I*** dan ***R*** gacha bo‘lgan tok kuchini olishimiz mumkin.

Faraz qilaylik,

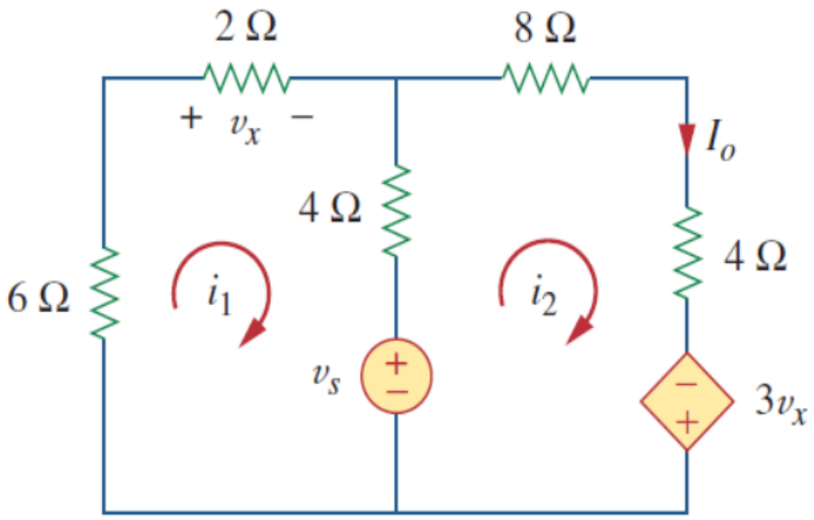
$U_s = 10\ V \rightarrow I = 2\ A$ ni beradi.

Chiziqlilik prinsipiga ko‘ra,

$U_s = 1\ V \rightarrow I = 0,2\ A$ ni beradi. Huddi shu qoidaga ko‘ra,

$I = 1\ mA \rightarrow U_s = 5\ mV$ ga bog‘liq bo‘lishi kerak.

4.1.1-masala: 4.2-rasmdagi elektr zanjiri uchun $U_s = 12\ V$ va $U_s = 24\ V$ bo‘lganda I_0 ni toping.



4.2-rasm.

Yechish: KVLni ikkita halqaga qo‘llaymiz.

$$\mathbf{6I_1 + 2I_1 + 4(I_1 - I_2) + U_s = 0}$$

$$\mathbf{12I_1 - 4I_2 + U_s = 0} \qquad (4.5)$$

$$\mathbf{4(I_2 - I_1) + 8I_2 + 4I_2 - 3U_x - U_s = 0}$$

$$\mathbf{-4I_1 + 16I_2 - 3U_x - U_s = 0} \qquad (4.6)$$

$\mathbf{U_x = 2I_1}$ → (4.6)

$$\mathbf{-10I_1 + 16I_2 - U_s = 0} \qquad (4.7)$$

(4.5) va (4.7) $\quad 2I_1 + 12I_2 = 0 \quad \rightarrow \quad \mathbf{I_1 = -6I_2}$

$$12(-6I_2) - 4I_2 + U_s = 0$$

$$-76I_2 + U_s = 0 \quad \rightarrow \quad \mathbf{I_2 = \frac{U_s}{76}}$$

Agar, $\boldsymbol{U_s = 12\ V}$ bo‘lsa,

$$\mathbf{I_0 = I_2 = \frac{12}{76}\ A}$$

Agar, $\boldsymbol{U_s = 24\ V}$ bo‘lsa,

$$\mathbf{I_0 = I_2 = \frac{24}{76}\ A}$$

Demak, manba qiymati ikki baravar oshirilsa, I_0 ikki barobar ko‘payishini ko‘rsatadi.

4.2. Superpozitsiya.

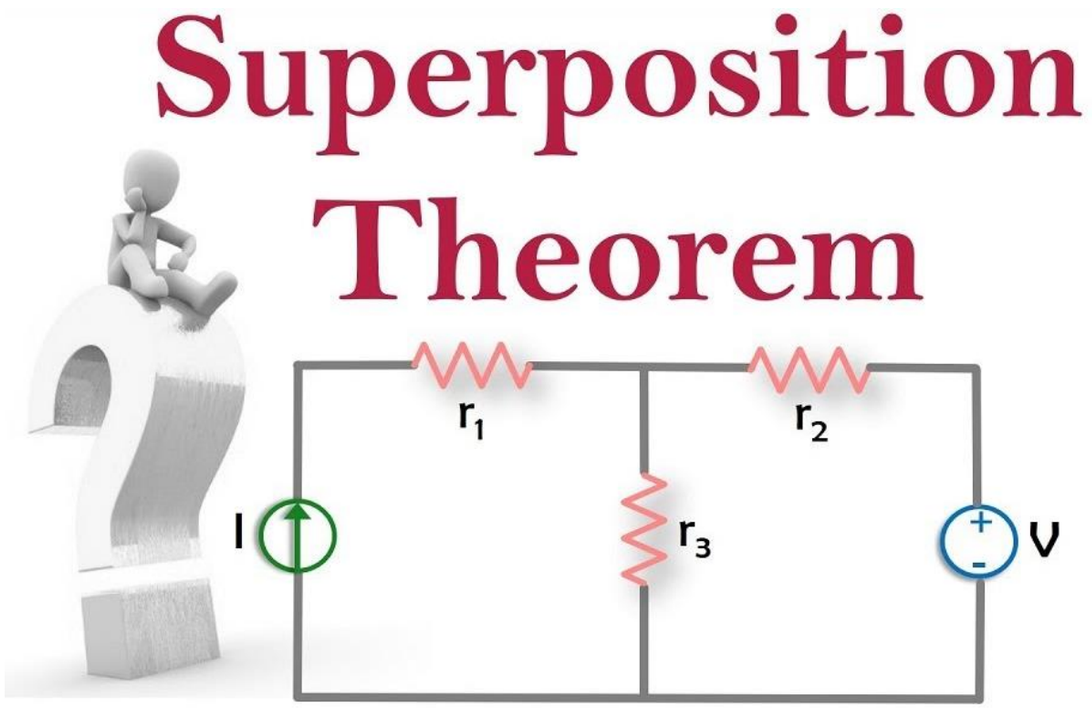


Photo source: [4] - https://i.ytimg.com/vi/vzuYQfU3NbE/maxresdefault.jpg

Chiziqli elektr zanjirlarida o‘zaro bog‘liq bo‘lmagan bir nechta manbalarning umumiy ta’siri alohida olingan har bir manba ta’siri natijalarining algebraik yig‘indisiga teng.

Ma’lumki, mesh (*kontur toklar*) tahlil usuliga binoan elektr zanjirida kuchlanish manbai ta’sirida shaxobchalardan o‘tuvchi kontur toklar kontur kuchlanishlarining chiziqli funksiyasidir.

Bu prinsip superpozitsiya (*ustma-ustlash*) prinsipi deyiladi.

Ushbu prinsipga asosan kontur yoki shaxobchadagi toklarni aniqlash usuli ustma-ustlash usuli deb ataladi.

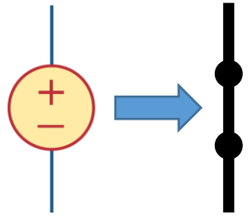
Superpozitsiya zanjirni tahlil qilish bilan cheklanib qolmaydi. U sabab va ta’sir bir-biri bilan chiziqli bog‘liq bo‘lgan ko‘plab sohalarda qo‘llaniladi.

Agar elektr zanjiri ikki yoki undan ortiq mustaqil manbalarga ega bo‘lsa, ma’lum bir o‘zgaruvchining (*kuchlanish yoki tok kuchi*) qiymatini aniqlash uchun tugun yoki mesh tahlili usullaridan foydalaniladi.

Boshqa usuli har bir mustaqil manbaning o‘zgaruvchiga qo‘shgan hissasini aniqlash va keyin ularni qo‘shish kerak bo‘ladi. Keyinchalik bunday yondashuv superpozitsiya sifatida tanilgan.

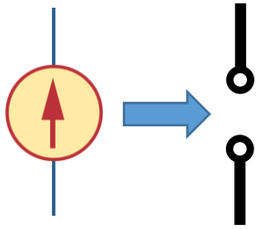
Kuchlanish va tok kuchi manbalarini 0 ga tenglashtirish qoidasi.

1. Mustaqil manbalar:



$u_s = 0$

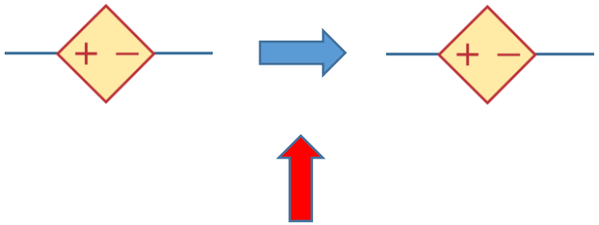
Qisqa tutashuv zanjir
(*short circuit*)



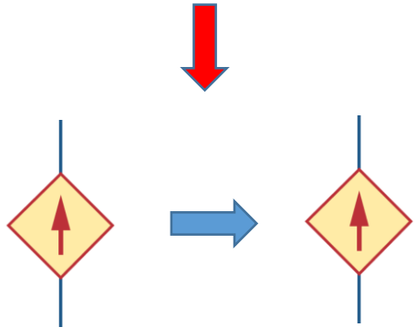
$i_s = 0$

Ochiq zanjir
(*open circuit*)

2. Bog‘liq bo‘lgan manbalar:



Manbalar zanjirning boshqa elementi bilan bog‘liq bo‘lganligi uchun zanjirda shundayligicha qoldiriladi



3. Hisoblash usullari:

- KVL;
- Mesh tahlili;
- Kuchlanishni bo ‘linish qoidasi;
- va boshqalar.

- KCL;
- Tugun tahlili;
- Tok kuchini bo ‘linish qoidasi;
- va boshqalar.

Superpozitsiya printsipi - chiziqli elementdagi kuchlanish (yoki tok kuchi) har bir mustaqil manba ta’sirida elementdagi kuchlanish (yoki tok kuchi)larning algebraik yig‘indisidir.

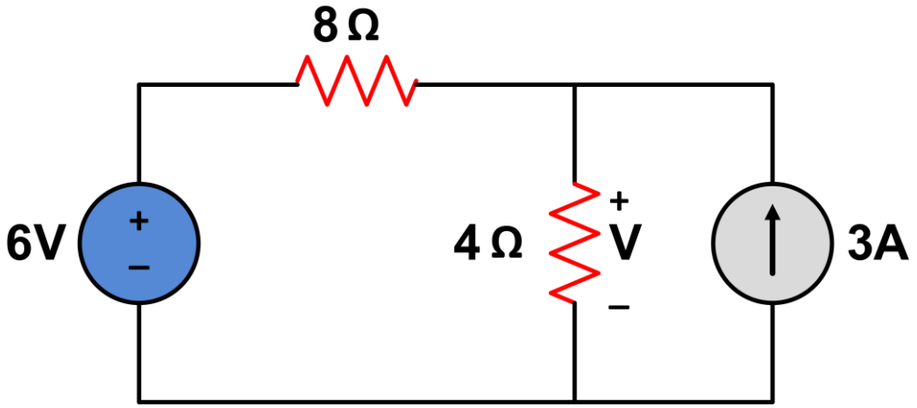


Photo source: [5] - https://electricalacademia.com/wp-content/uploads/2016/12/super-position-1-655x300.gif

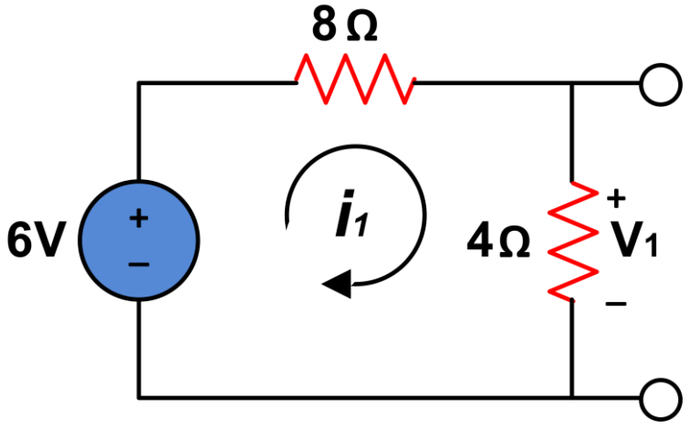


Photo source: [6] - https://electricalacademia.com/wp-content/uploads/2016/12/super-position-2-469x300.gif

$$U = U_1 + U_2$$

$$I = I_1 + I_2$$

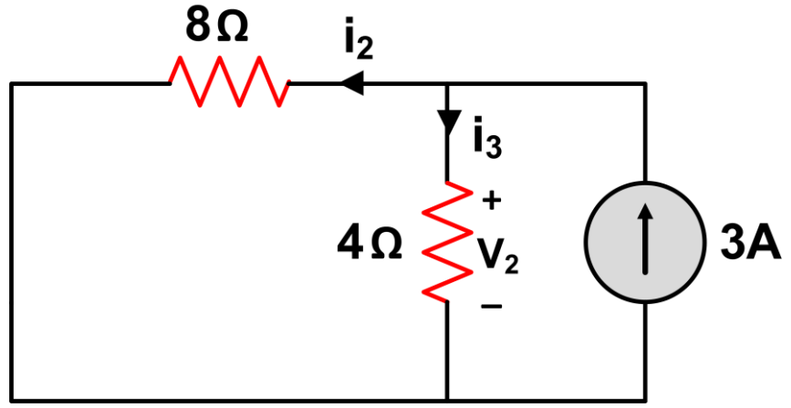


Photo source: [7] - https://electricalacademia.com/wp-content/uploads/2016/12/super-position-3-559x300.gif

Superpozitsiya prinsipini qo‘llash uchun biz ikkita narsani yodda tutishimiz kerak:

1. Boshqa barcha mustaqil manbalar o‘chirilgan holda bir vaqtning o‘zida bitta mustaqil manba ko‘rib chiqiladi.

Bu har bir kuchlanish manbasini 0 V ga almashtirishni anglatadi (*yoki qisqa zanjirda*) va har bir tok kuchi manbasini 0 A (*yoki ochiq zanjirda*) ga almashtiramiz.

Shunday qilib, biz oddiyroq va boshqariladigan elektr zanjirini hosil qilamiz.

2. Bog‘liq manbalar o‘chirilmagan holda qoldiriladi, chunki ular zanjirning biron elementi tomonidan boshqariladi.

Superpozitsiya yordamida elektr zanjirlarni tahlil qilish bitta asosiy kamchilikka ega.

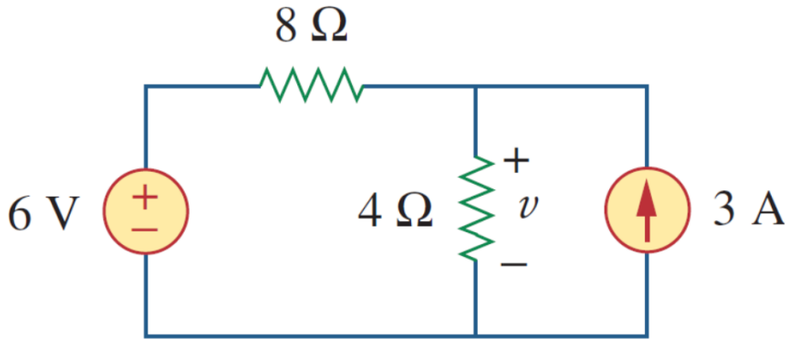
Bu ko‘proq ish bilan bog‘liq bo‘lishi mumkin.

Agar elektr zanjirlari uchta mustaqil manbaga ega bo‘lsa, har birini tegishli individual manba sifatida ajratib uchta oddiy elektr zanjirlarini tahlil qilish kerak bo‘ladi.

Shunday qilib, superpozitsiya chiziqlilikka asoslangan. Shu sababli, u har bir manbadan kelib chiqadigan quvvatga ta’sir qilish uchun qo‘llanilmaydi, chunki rezistor tomonidan sarflangan quvvat kuchlanish yoki tok kuchining kvadratiga bog‘liq.

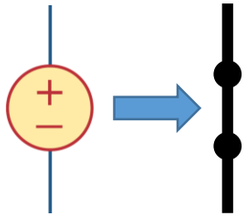
Quvvat qiymati kerak bo‘lsa, element orqali tok kuchi (*yoki kuchlanish*) birinchi navbatda superpozitsiya yordamida hisoblanishi kerak.

4.2.1-masala: 4.3-rasmda ko‘rsatilgan elektr zanjiridagi U kuchlanishni superpozitsiya teoremasidan foydalanib toping.

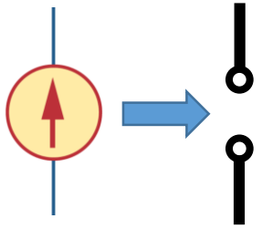


4.3-rasm.

Yechish: $\boldsymbol{U = U_1 + U_2}$

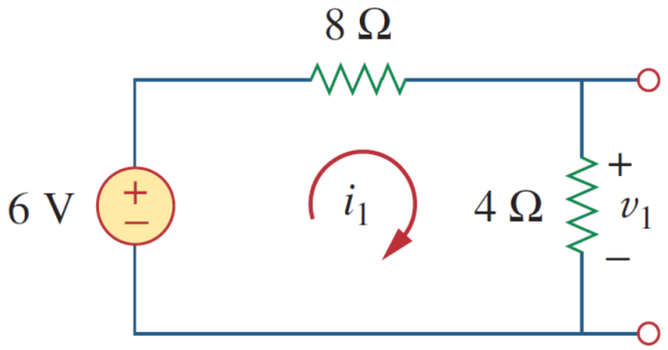


$\boldsymbol{u_s = u_{s.c} = 0}$



$\boldsymbol{i_s = i_{o.c} = 0}$

U_1 hisoblash zanjiri:

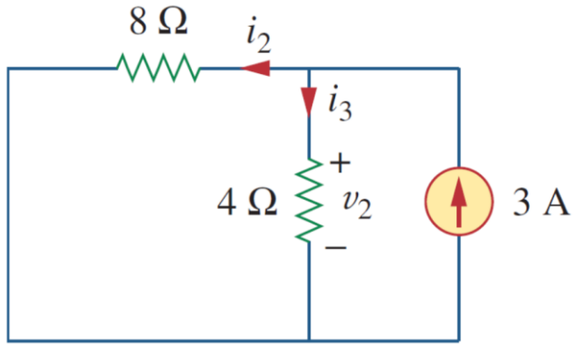


$$12I_1 - 6 = 0 \rightarrow I_1 = 0{,}5\ A$$

$$U_1 = 4I_1 = 2\ V$$

VDR: $$U_1 = \frac{4}{4+8}(6) = 2\ V$$

U_2 hisoblash zanjiri:



CDR: $$I_3 = \frac{8}{4+8}(3) = 2\ A$$

$$U_2 = 4I_3 = 8\ V$$

Umumiy natija: $U = U_1 + U_2 = 2 + 8 = \mathbf{10\ V}$

4.3. Manbani o‘zgartirish.

Biz ketma-ket - parallel kombinatsiya va wye-delta transformatsiyasi elektr zanjirlarni soddalashtirishga yordam berishini aniqladik.

Manbani o‘zgartirish elektr zanjirlarni soddalashtirish uchun yana bir vositadir. Ushbu vositalarning asosi ekvivalentlik tushunchasidir.

Ekvivalent zanjiri bu ***U - I*** xarakteristikalari dastlabki zanjir bilan bir xil bo‘lgan zanjirdir.

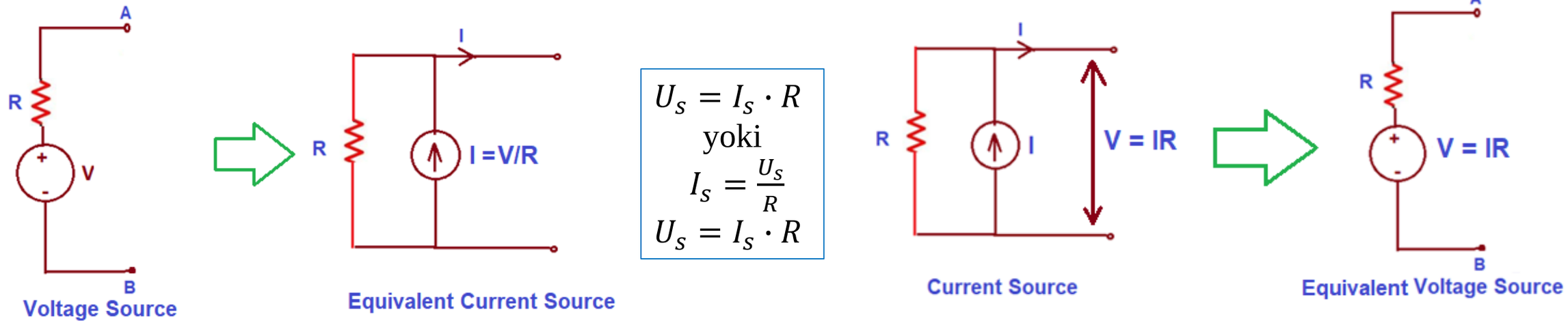
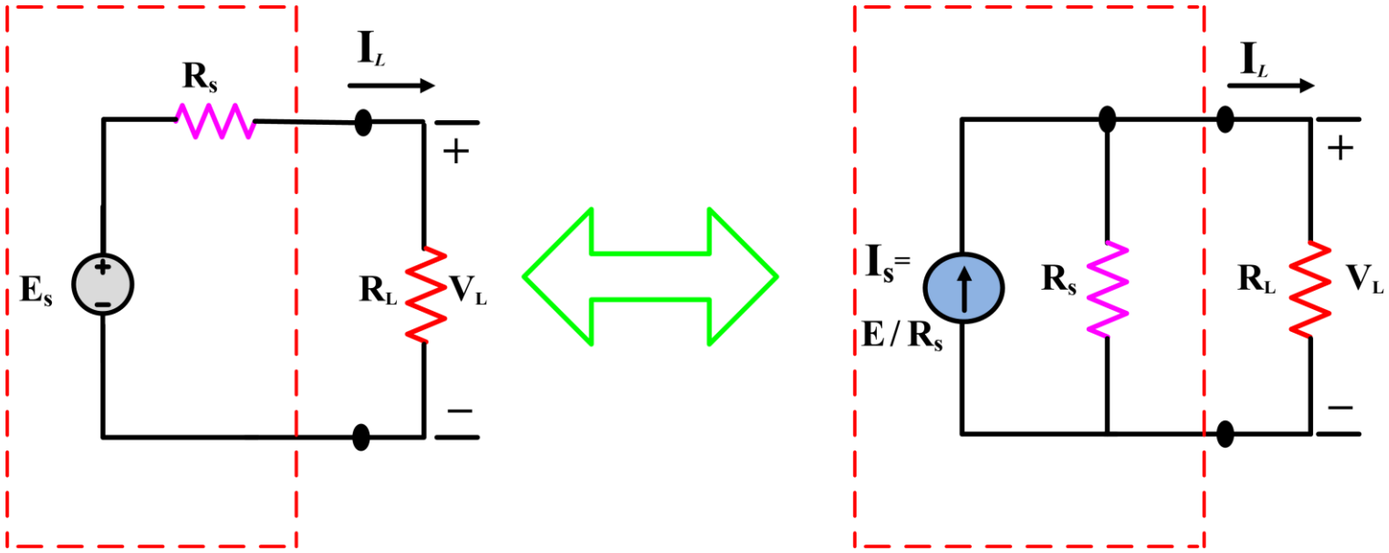


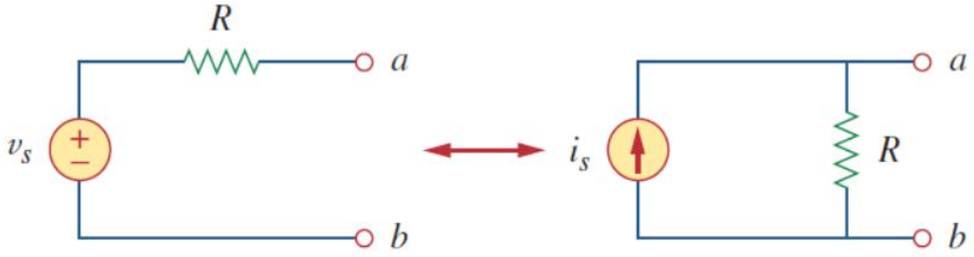
Photo source: [8] - https://electricalbaba.com/wp-content/uploads/2020/05/Source-Transformation-voltage-to-current-source-conversion.png

Photo source: [9] - https://electricalbaba.com/wp-content/uploads/2020/05/Source-Transformation-current-source-to-voltage-source-conversion.png

Mustaqil manbalarni transformatsiyasi



(a) Voltage source *(b) Current source*



Bog‘liq bo‘lgan manbalarni transformatsiyasi

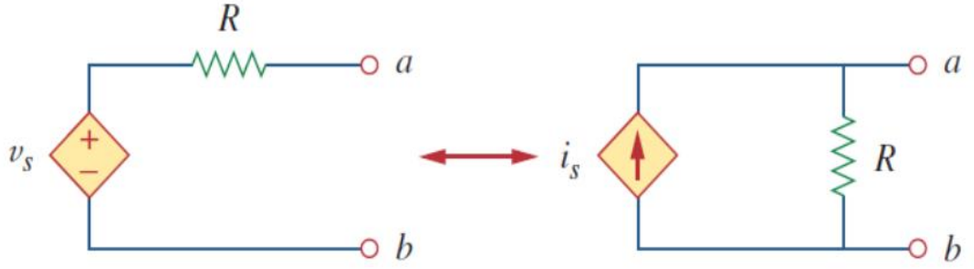
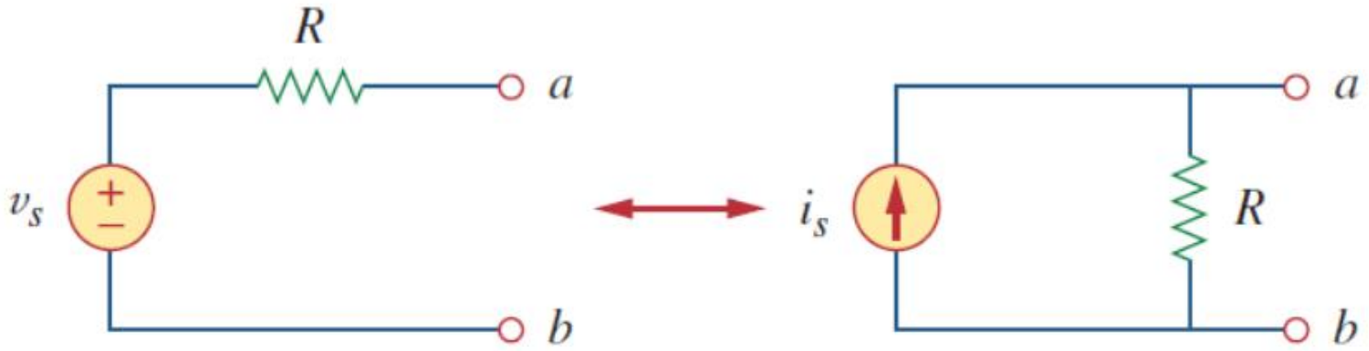


Photo source: [10] - https://electricalacademia.com/wp-content/uploads/2017/01/source-transformation-1.gif

Manbani transformatsiyalash - bu U_s kuchlanish manbasini R rezistor bilan ketma-ket va tok kuchi manbasi I_s bilan R rezistorni parallel ravishda almashtirish jarayoni tushiniladi.

$$U_s = U_{oc} = I_s \cdot R$$



$$I_{sc} = I_s = \frac{U_s}{R}$$

4.5-rasm. Mustaqil manbalarni o‘zgartirish.

U ***I***

Ketma-ket ⟹ Parallel

R=const

U ***I***

Ketma-ket ⟸ Parallel

4.5-rasmdagi ikkita elektr zanjirlar ekvivalentdir - *a*-*b* terminallarida bir xil kuchlanish-toki kuchi munosabatiga ega bo‘lish sharti bilan ifodalanadi.

Ular haqiqatan ham ekvivalent ekanligini ko‘rsatish oson. Agar manbalar o‘chirilgan bo‘lsa, ikkala elektr zanjirida *a*-*b* terminallaridagi ekvivalent qarshilik $\boldsymbol{R}$ dir.

Shuningdek, *a*-*b* terminallari qisqa elektr zanjirida bo‘lsa, *a* dan *b* ga o‘tadigan qisqa elektr zanjiridagi tok kuchi $I_{sc} = U_s/R$ bo‘ladi.

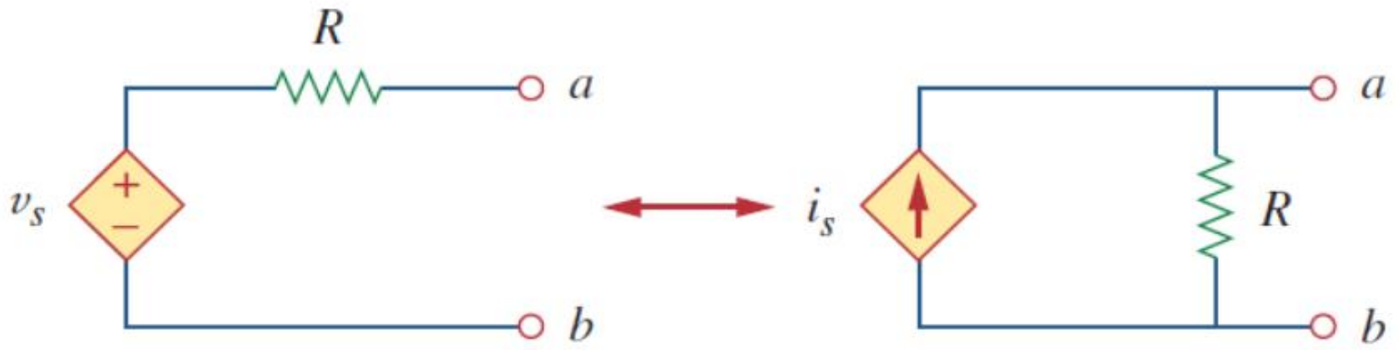
Chap tomon va o‘ng tomondagi elektr zanjiri uchun $I_{sc} = I_s$. Shunday qilib, ikkita elektr zanjirlari ekvivalent bo‘lishi uchun $I_s = U_s/R$.

Demak, manbani o‘zgartirish quyidagi shartni talab qiladi:

$$\boldsymbol{U_s = I_s \cdot R} \quad \textbf{yoki} \quad \boldsymbol{I_s = \frac{U_s}{R}} \qquad \textbf{(4.8)}$$

Manbani o‘zgartirish, bog‘liq bo‘lgan manbalar uchun ham amal qiladi. 4.6-rasmda bog‘liq bo‘lgan kuchlanish manbasi rezistor bilan ketma-ket va bog‘liq bo‘lgan tok kuchi manbasi rezistor bilan parallel ravishda transformatsiya qilinadi. Bunda ham (4.8) tenglama birdek amal qiladi.

$$U_s = I_s \cdot R \quad \textbf{yoki} \quad I_s = \frac{U_s}{R} \qquad (4.8)$$



4.6-rasm. Bog‘liq bo‘lgan manbalarni o‘zgartirish.

Manba transformatsiyasi elektr zanjir manipulyatsiyalarni sxema tahlilini osonlashtirishga imkon beruvchi kuchli vositadir. Lekin, manbani o‘zgartirayotganda quyidagilarni yodda tutishimiz kerak.

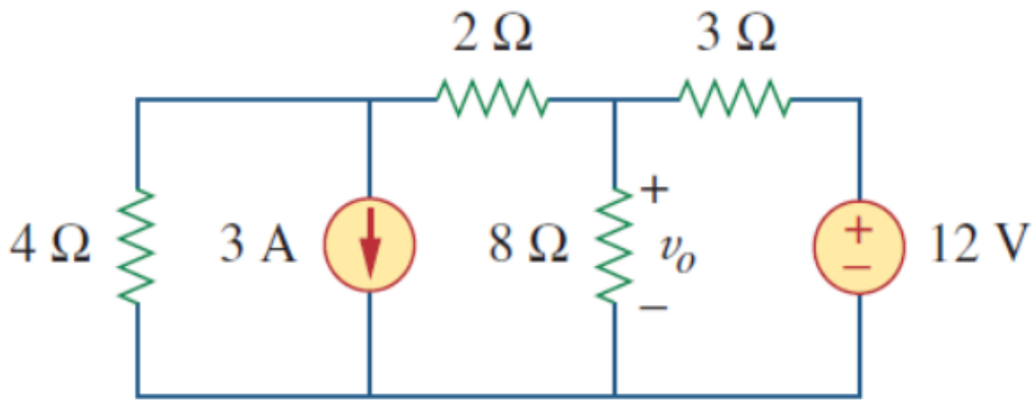
1. 4.5-rasmga (yoki 4.6-rasm) e’tibor beradigan bo‘lsak, tok kuchi manbaining o‘qi kuchlanish manbasining musbat terminali tomon yo‘naltirilgan.

2. 4.7 tenglamaga e’tibor qaratsak, R=0 bo‘lganda manbani o‘zgartirish mumkin emas, bu ideal kuchlanish manbai bilan bog‘liq.

Lekin, amalda ideal bo‘lmagan kuchlanish manbai uchun R≠0.

Huddi shuningdek, $R = \infty$ bo‘lgan ideal tok kuchi manbai cheklangan kuchlanish manbai bilan almashtirilishi mumkin emas.

4.3.1-masala: 4.7-rasmdagi sxemada U_0 ni topish uchun manba transformatsiyasidan foydalaning.



4.7-rasm.

CDR:

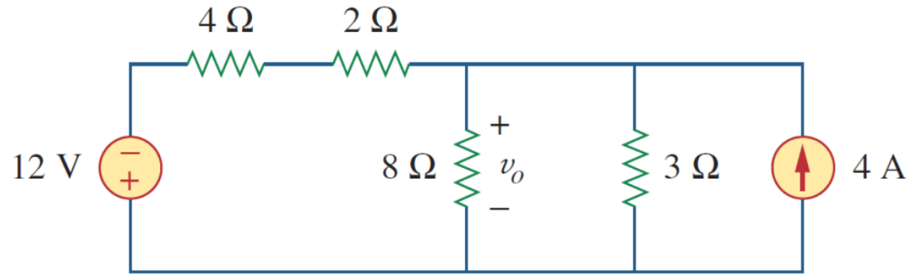
$$I_2 = \frac{R_1}{R_1+R_2} \cdot I = \frac{2}{2+8} \cdot 2 = 0{,}4\ A$$

$$U_0 = R_2 \cdot I = 8 \cdot 0{,}4 = 3{,}2\ V$$

Ohm`s law:

$$U_0 = (8||2)(2A) = \frac{8 \cdot 2}{10}(2) = 3{,}2\ V$$

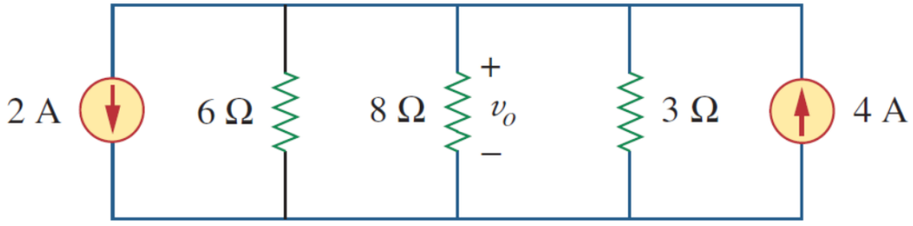
Yechish:

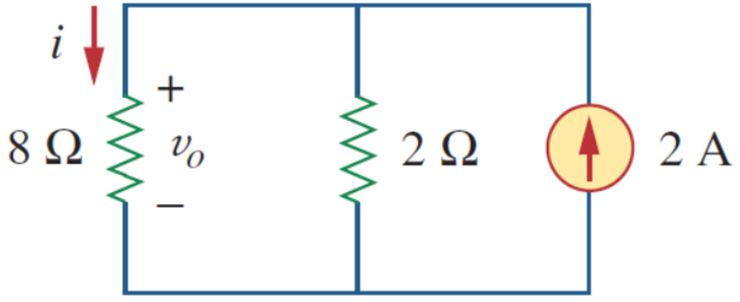


$$U_s = I_s \cdot R = 3 \cdot 4 = 12\ \text{V}$$

$$R_{um} = 4 + 2 = 6\ \Omega$$

$$I_s = \frac{U_s}{R} = \frac{12}{6} = 2\ A$$





$$I_s = i_1 + i_2 = -2 + 4 = 2\ A$$

$$R_{um} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{6 \cdot 3}{6 + 3} = 2\ \Omega$$

FOYDALANILGAN MANBALAR:

1. https://1.bp.blogspot.com/-OqYUMOc3iW8/YQZ1XZag4MI/AAAAAAAABVw/N0Cy2YwwGbEB96BmhvurgSt0rdmf4ojKwCLcBGAsYHQ/s434/Linear%2BElement%2BVI%2BCharacteristics.png
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E'TIBORINGIZ UCHUN RAHMAT!!!