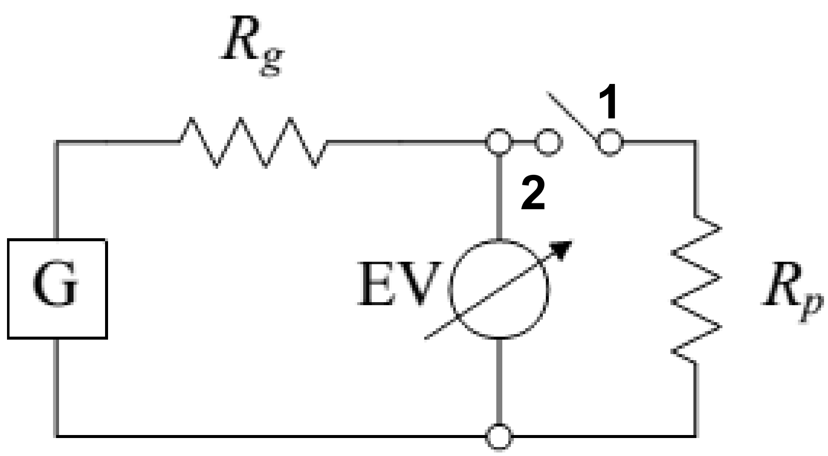
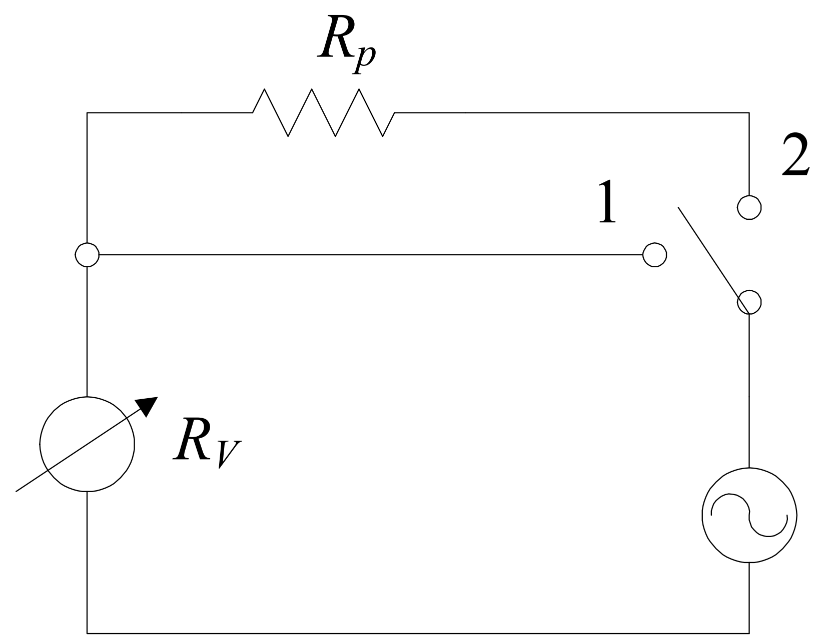
Merenje električnih veličina II

12.11.2020.

MERENJE IZLAZNE OTPORNOSTI GENERATORA (lab. vežba)

MERENJE ULAZNE OTPORNOSTI VOLTMETRA (lab. vežba)

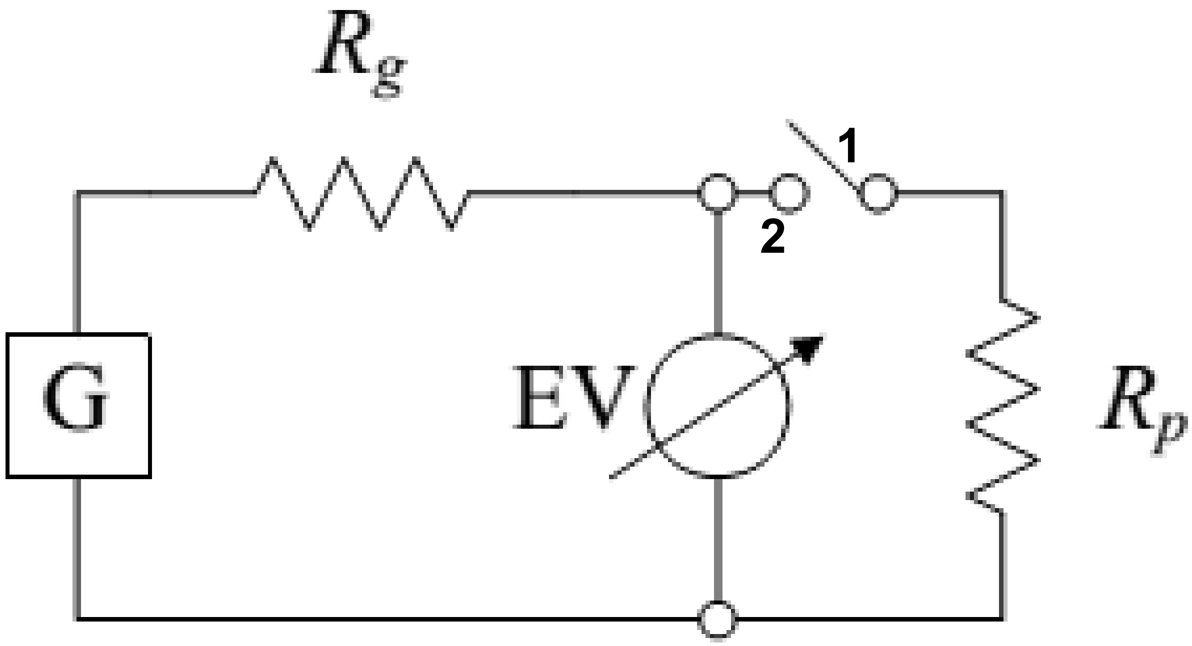




$$R_g = f(R_p, U_1, U_2) = ?$$

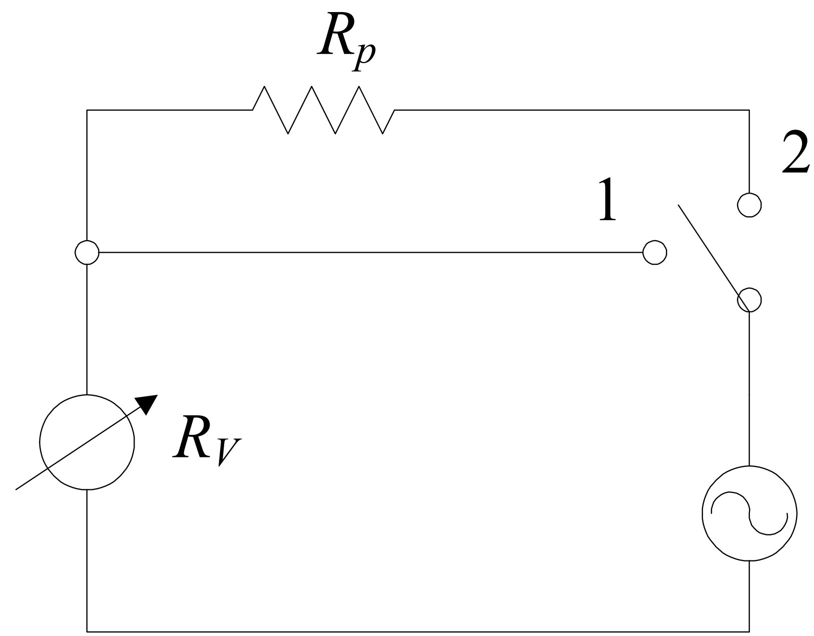
$$R_V = f(R_p, U_1, U_2) = ?$$

MERENJE IZLAZNE OTPORNOSTI GENERATORA (lab. vežba)



$$R_g = R_p \frac{U_1 - U_2}{U_2}$$

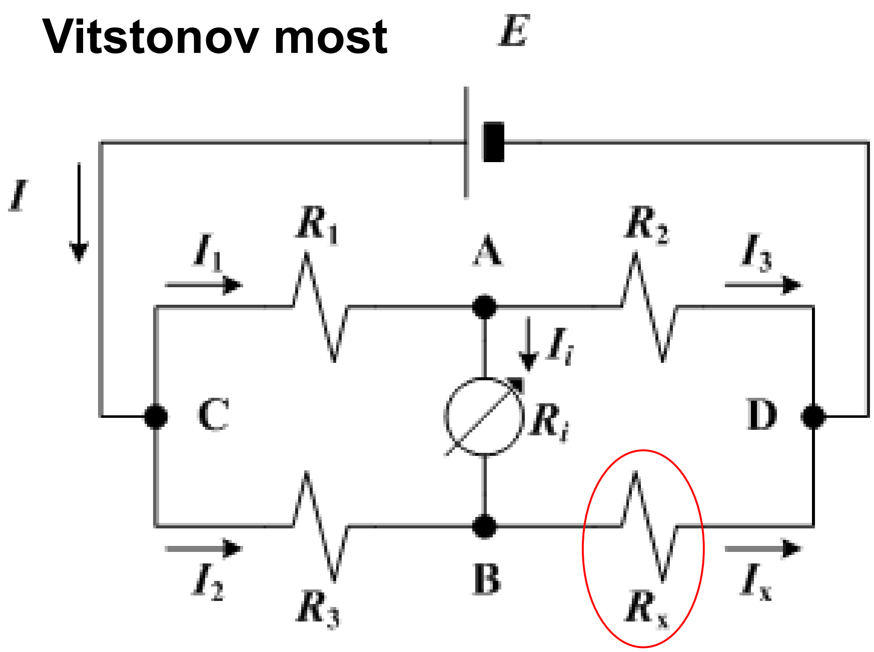
MERENJE ULAZNE OTPORNOSTI VOLTMETRA (lab. vežba)



$$R_V = R_p \frac{U_2}{U_1 - U_2}$$

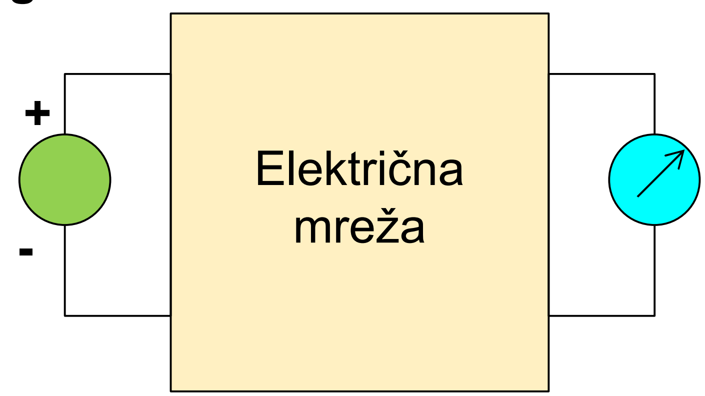
MERENJE OTPORNOSTI MOSTOM

Vitstonov most



Primer mosta za merenje otpornosti *R*$_x$

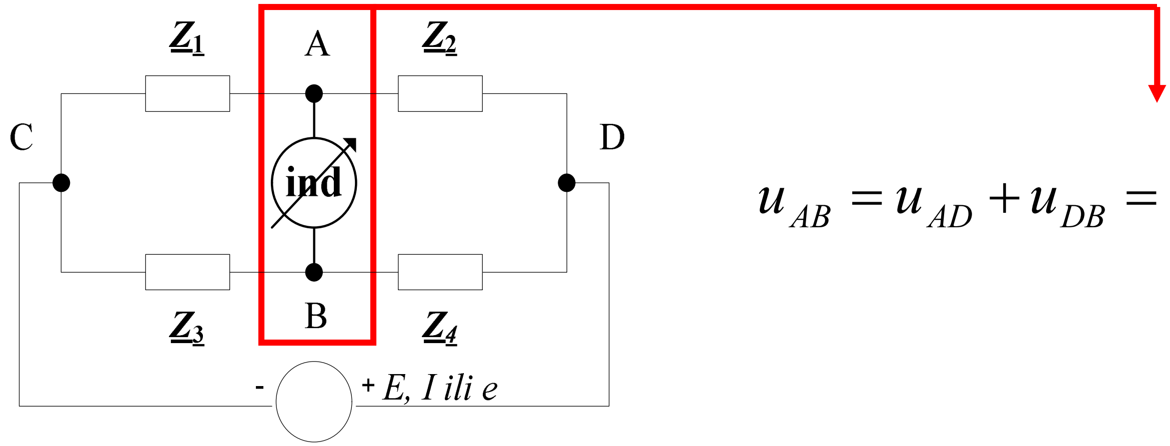
1847. - "Otporna vaga"



Opšta konfiguracija mernog mosta

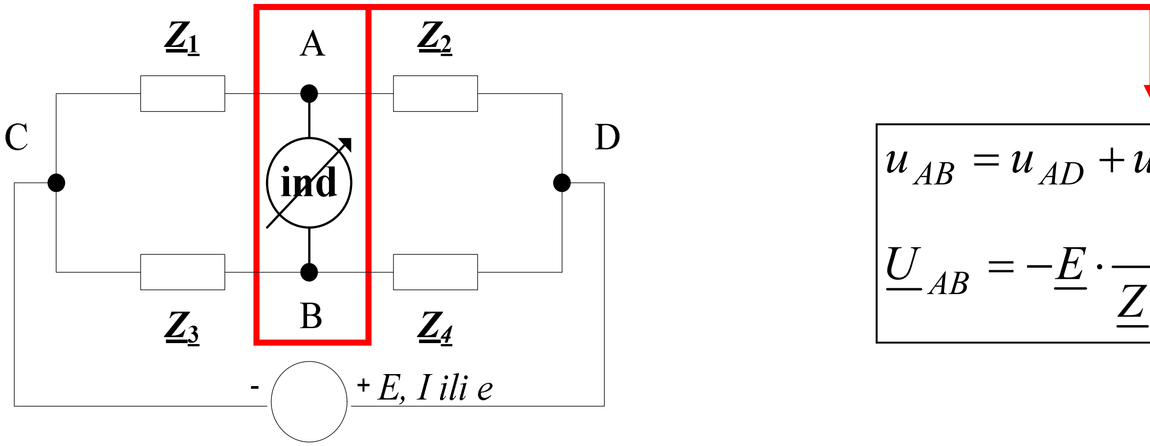
Indikator (nul-detektor) može biti:
galvanometar,
osetljiv ampermetar,
voltmetar,
osciloskop,
slušalice

OPŠTA KONFIGURACIJA MERNOG MOSTA



$$u_{AB} = u_{AD} + u_{DB} = ? = f(elemenata\ kola)$$

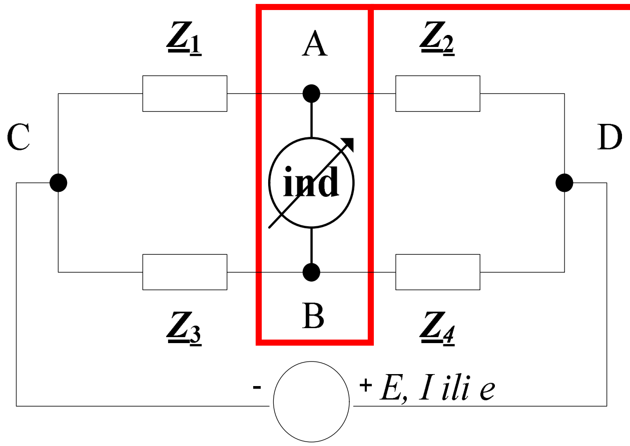
OPŠTA KONFIGURACIJA MERNOG MOSTA



$$u_{AB} = u_{AD} + u_{DB}$$

$$\underline{U}_{AB} = -\underline{E} \cdot \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2} + \underline{E} \cdot \frac{\underline{Z}_4}{\underline{Z}_3 + \underline{Z}_4}$$

OPŠTA KONFIGURACIJA MERNOG MOSTA



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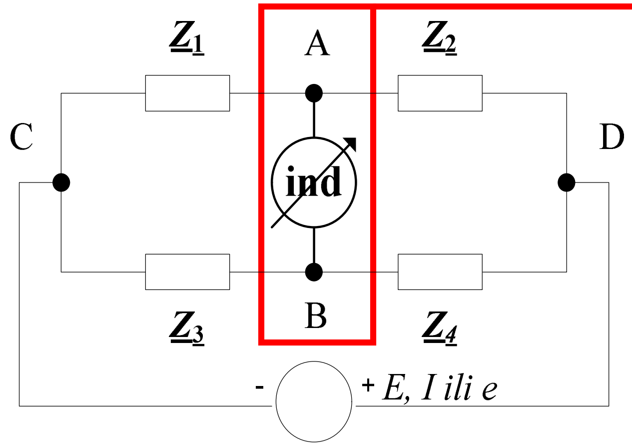
u_{AB} **?** **0**

= **ili** **≠** **?**

OPŠTA KONFIGURACIJA MERNOG MOSTA



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MOST

uravnotežen:

cilj: $u_{AB} = 0$

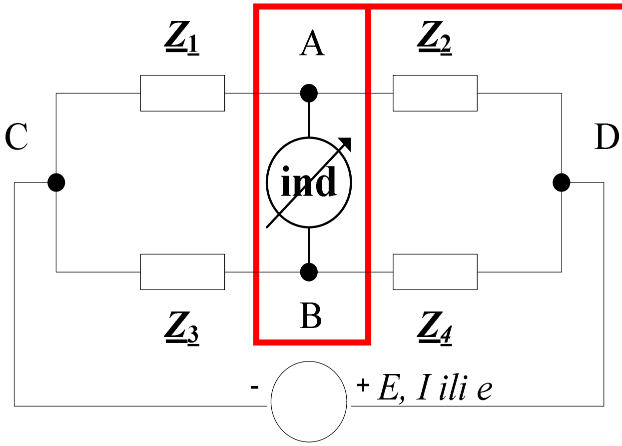
$\Rightarrow \underline{Z}_1 \underline{Z}_4 = \underline{Z}_2 \underline{Z}_3$

ova relacija važi SAMO za uravnotežen most!!!

neuravnotežen:

cilj: $u_{AB} \neq 0$

OPŠTA KONFIGURACIJA MERNOG MOSTA



$$u_{AB} = u_{AD} + u_{DB}$$

$$\underline{U}_{AB} = -\underline{E}\cdot\frac{\underline{Z}_2}{\underline{Z}_1+\underline{Z}_2} + \underline{E}\cdot\frac{\underline{Z}_4}{\underline{Z}_3+\underline{Z}_4}$$

MOST

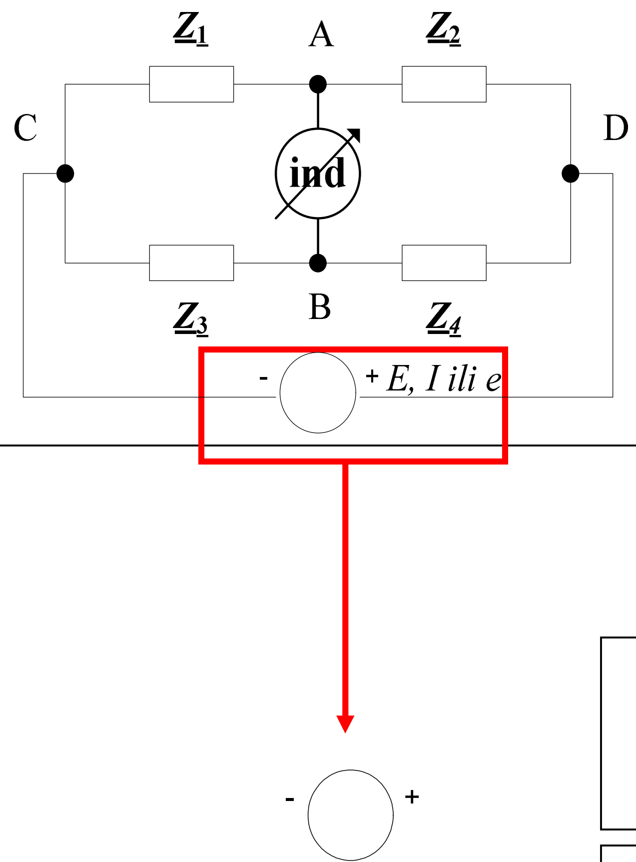
uravnotežen most
PRIMENA

Npr.
Određivanje nepoznatog elementa kola

neuravnotežen most
PRIMENA

Npr.
Određivanje promene nepoznatog elementa kola

OPŠTA KONFIGURACIJA MERNOG MOSTA

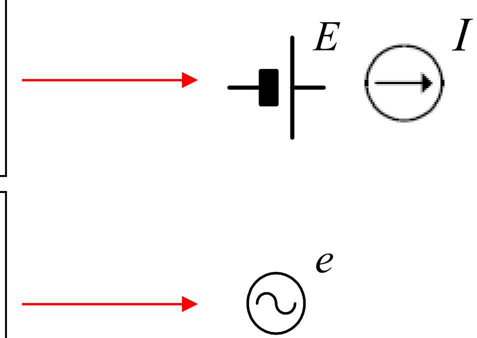


$$u_{AB} = u_{AD} + u_{DB}$$

$$\underline{U}_{AB} = -\underline{E} \cdot \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2} + \underline{E} \cdot \frac{\underline{Z}_4}{\underline{Z}_3 + \underline{Z}_4}$$

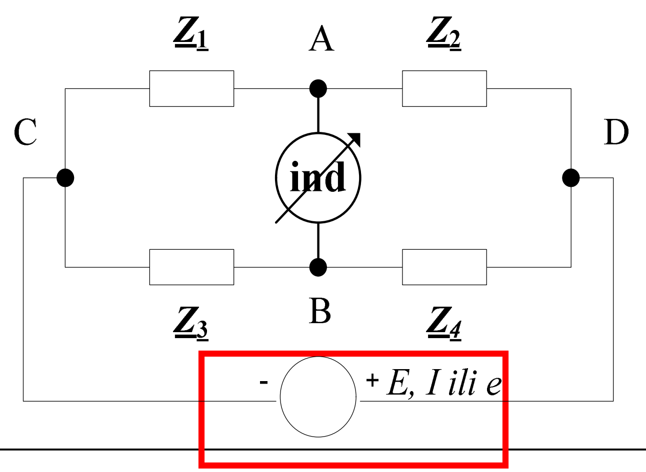
?

?



E ili $\neq$ e ?

OPŠTA KONFIGURACIJA MERNOG MOSTA



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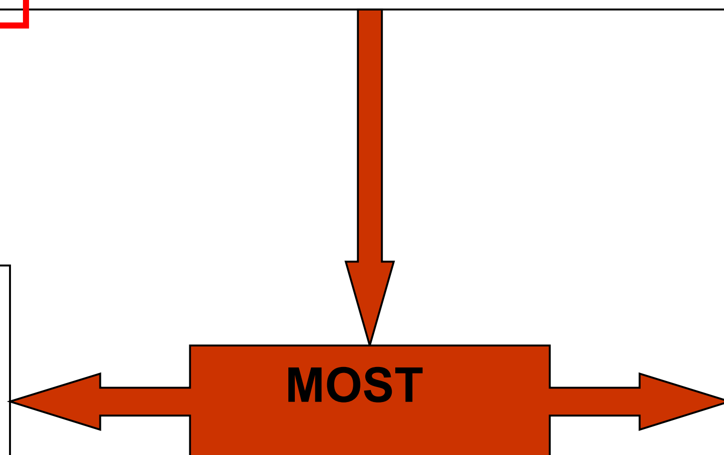
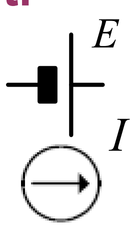


za jednosmernu struju:

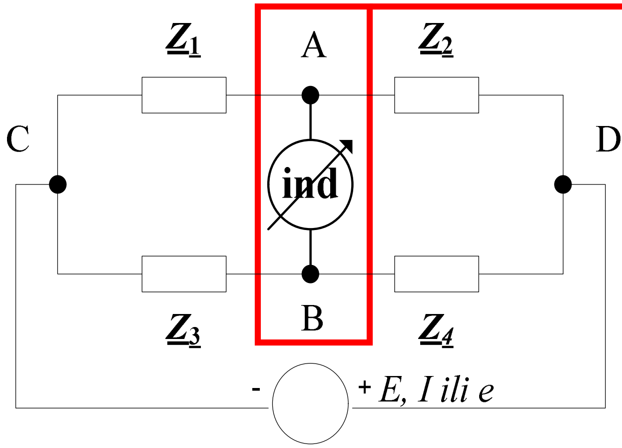
- **Z_i su otpornosti**
- **DC generator**



za naizmeničnu struju:

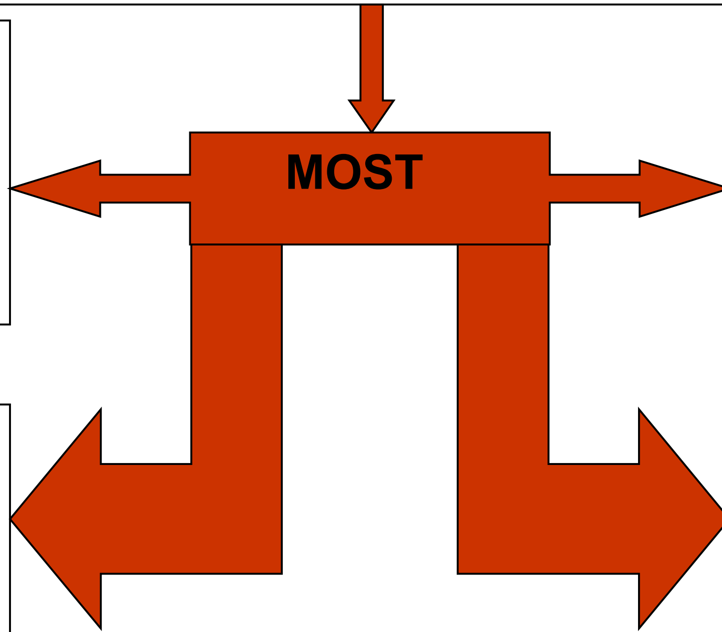
- **Z_i su paralelne i/ili redne veze otpornosti, induktivnosti, kapacitivnosti**
- **AC generator**

OPŠTA KONFIGURACIJA MERNOG MOSTA



$$u_{AB} = u_{AD} + u_{DB}$$

$$\underline{U}_{AB} = -\underline{E}\cdot\frac{\underline{Z}_2}{\underline{Z}_1+\underline{Z}_2} + \underline{E}\cdot\frac{\underline{Z}_4}{\underline{Z}_3+\underline{Z}_4}$$



uravnotežen:

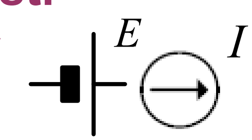
cilj: $u_{AB}=0$

$\Rightarrow \underline{Z}_1\,\underline{Z}_4 = \underline{Z}_2\,\underline{Z}_3$

neuravnotežen:

cilj: $u_{AB}\neq 0$

za jednosmernu struju:
- **Z_i su otpornosti**
- **DC generator**



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- **Z_i su paralelne i/ili redne veze otpornosti, induktivnosti, kapacitivnosti**
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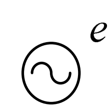
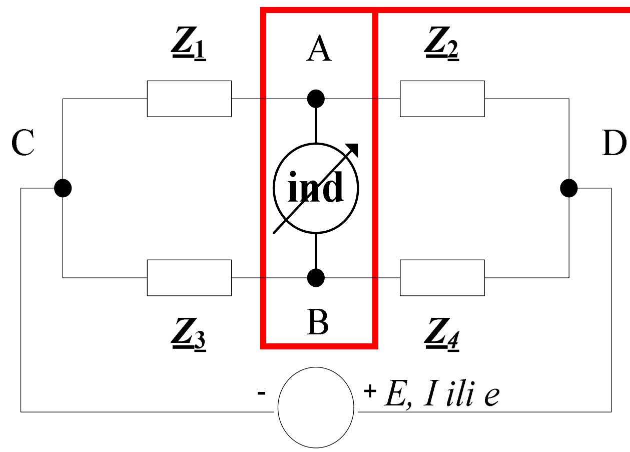


OPŠTA KONFIGURACIJA MERNOG MOSTA



$$u_{AB} = u_{AD} + u_{DB}$$

$$\underline{U}_{AB} = -\underline{E} \cdot \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2} + \underline{E} \cdot \frac{\underline{Z}_4}{\underline{Z}_3 + \underline{Z}_4}$$

Osetljivost mosta je osnovna karakteristika mosta.
Od interesa je vrednost osetljivosti u blizini ravnoteže mosta.

$$S_U = \frac{\partial \underline{U}_{AB}}{\dfrac{\partial \underline{Z}_x}{\underline{Z}_x}} = \underline{Z}_x \frac{\partial \underline{U}_{AB}}{\partial \underline{Z}_x}$$

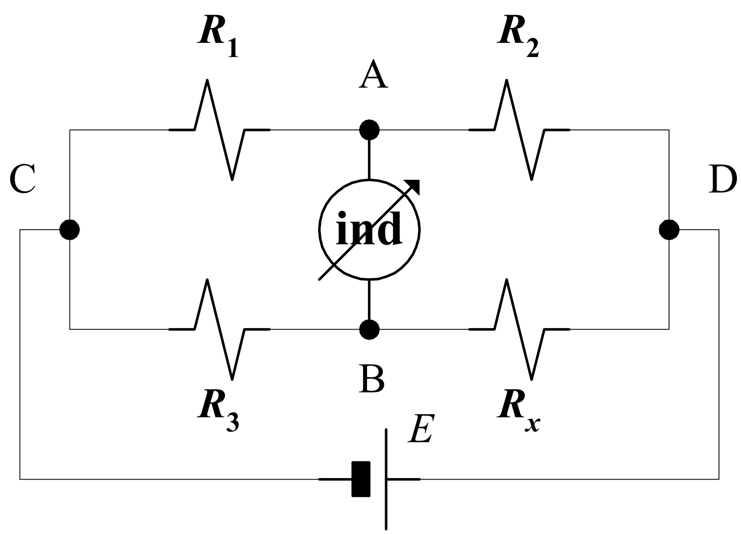
Naponska osetljivost mosta

$$S_I = \frac{\partial \underline{I}_{AB}}{\partial \underline{Z}_x}$$

Strujna osetljivost mosta

MERENJE OTPORNOSTI MOSTOM

Vitstonov most - uravnoteženi



Odrediti nepoznatu otpornost R_x u funkciji elemenata kola. Smatrati da je indikator idealan voltmetar.

Za uravnotežen most važi $\Rightarrow$

$$R_1 R_x = R_2 R_3$$

$$R_x = \frac{R_2 R_3}{R_1}$$

Za određivanje nepoznate otpornosti R_x je potrebno poznavati jedan od otpornika i odnos preostala dva otpornika

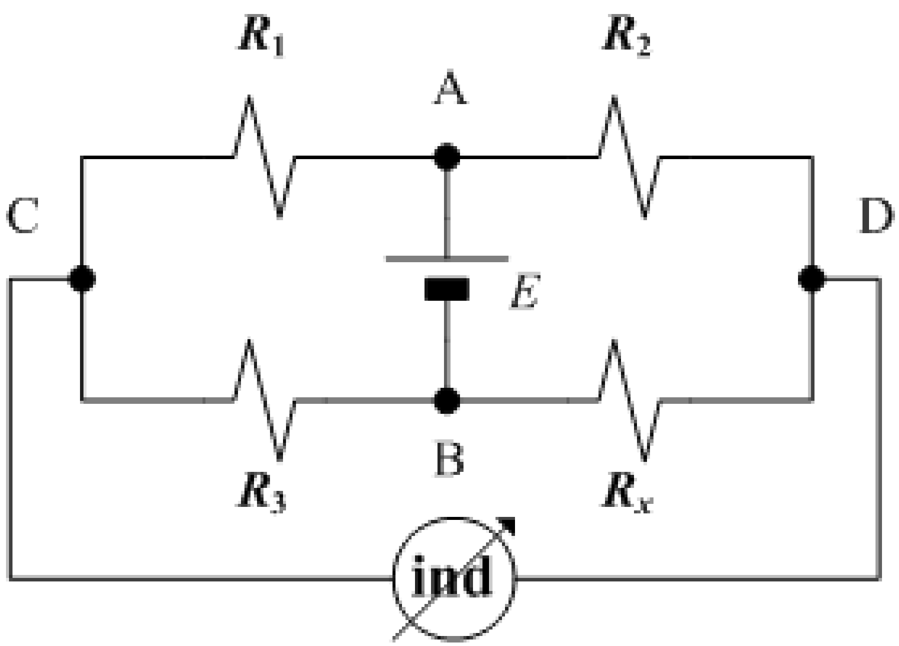
Napajanje (napon i impedansa) ne utiče na vrednost R_x – voditi računa o maksimalnoj snazi otpornika!

Osetljivost i izlazna impedansa nul-detektora ne utiču na vrednost R_x

Merni opseg: od 1 Ω (zbog otpornosti pristupnih vodova) do 10 MΩ.

MERENJE OTPORNOSTI MOSTOM

Vitstonov most - uravnoteženi

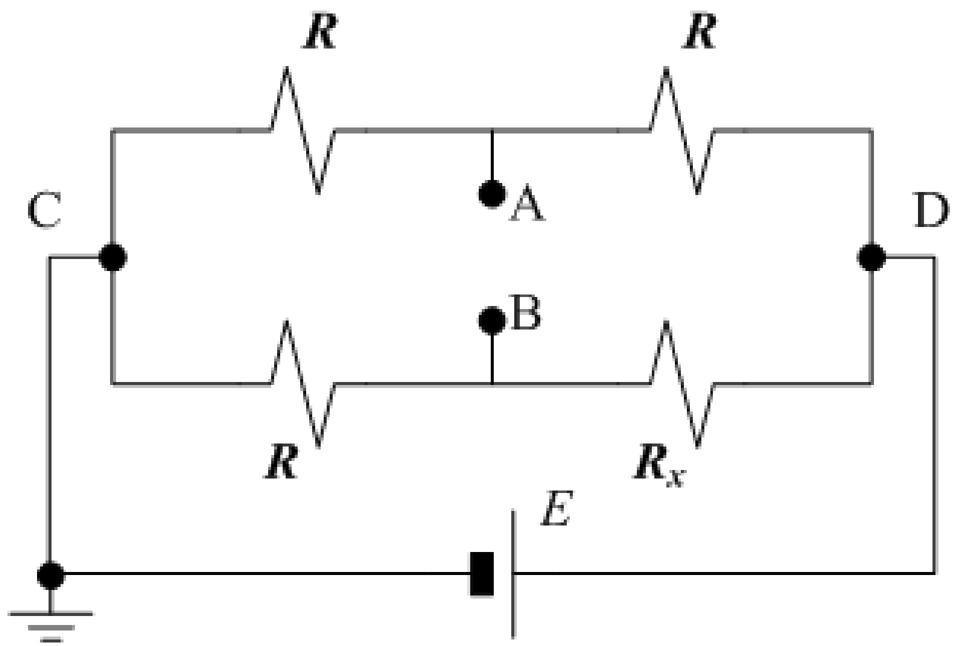


Koji je uslov ravnoteže?

MERENJE OTPORNOSTI MOSTOM

Vitstonov most - uravnoteženi

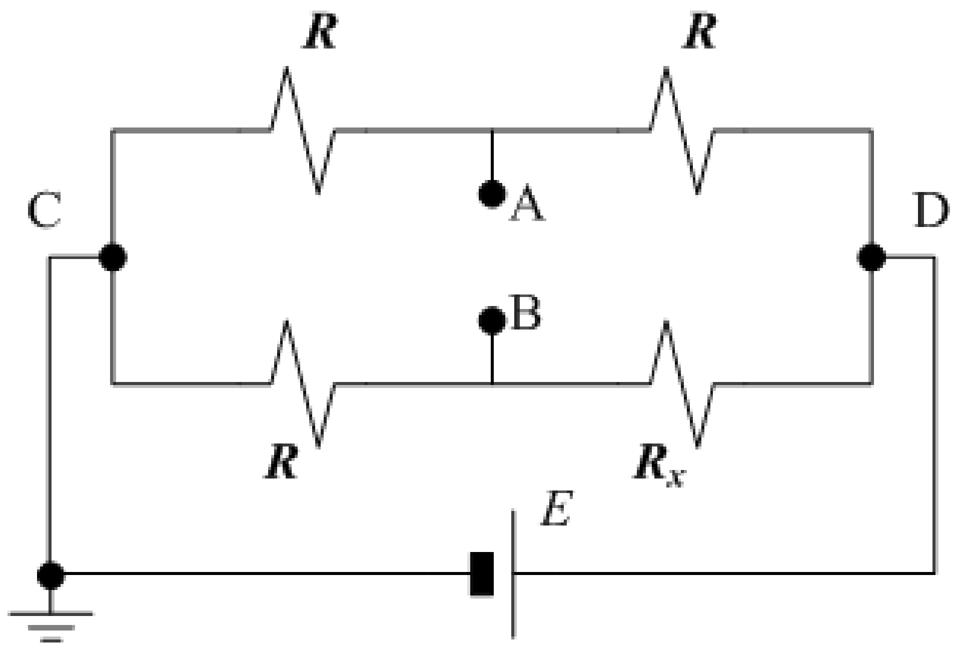
Kako povezati osciloskop kao nul-detektor?



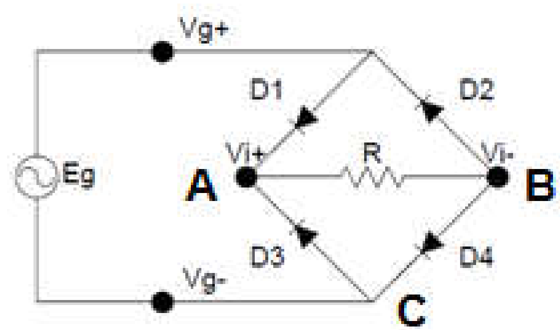
MERENJE OTPORNOSTI MOSTOM

Vitstonov most - uravnoteženi

Kako povezati osciloskop kao nul-detektor?

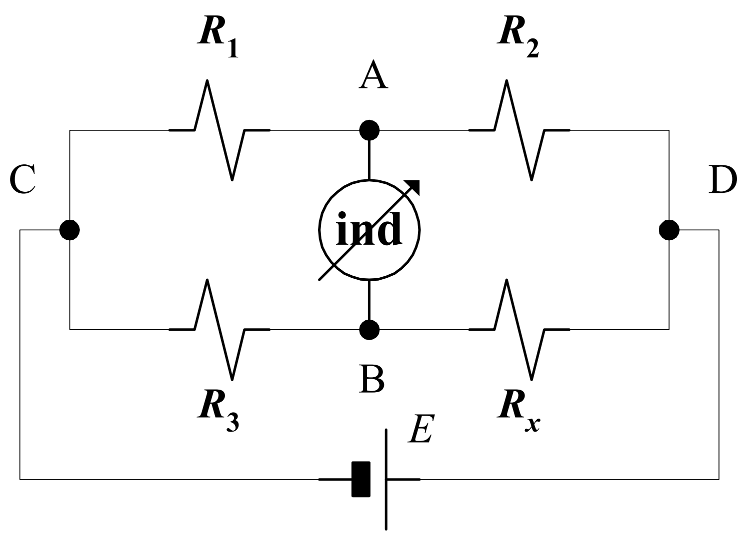


Analogija: kolo za dvostrano ispravljanje



MERENJE OTPORNOSTI MOSTOM

Vitstonov most - uravnoteženi



Kolika je naponska osetljivost mosta?

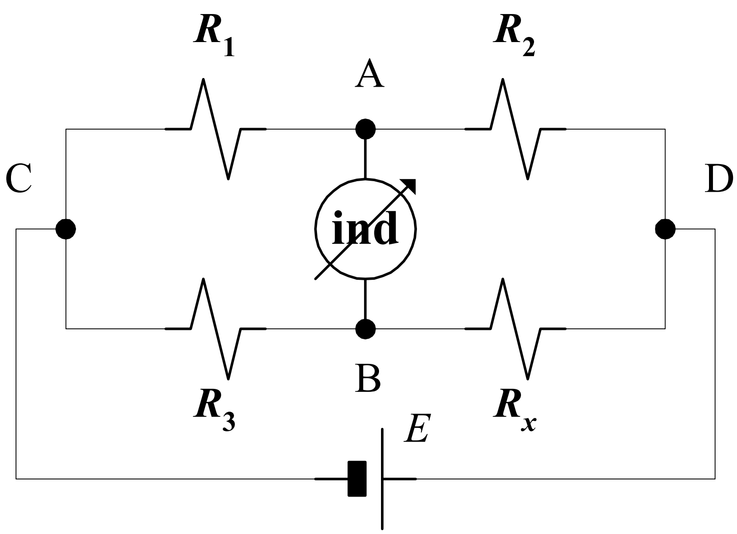
$$u_{AB} = u_{AD} + u_{DB} = -E \cdot \frac{R_2}{R_1 + R_2} + E \cdot \frac{R_x}{R_x + R_3}$$

$$S_U = R_x \frac{\partial u_{AB}}{\partial R_x} = E \frac{R_3 R_x}{\left(R_x + R_3\right)^2}$$

$$R_x = \frac{R_2 R_3}{R_1} \Rightarrow S_U = E \frac{\frac{R_2}{R_1}}{\left(1 + \frac{R_2}{R_1}\right)^2} \Rightarrow S_{U\,\max} = \frac{E}{4}, \quad za \quad R_1 = R_2$$

MERENJE OTPORNOSTI MOSTOM

Vitstonov most – neuravnoteženi



Odrediti promenu nepoznate otpornosti R_x u funkciji elemenata kola i napona u_{AB}. Smatrati da je indikator idealan voltmetar.

Poznato je da:

$$R_1 = R_2 = R_3 = R$$

$$R_x = R \pm \Delta R_x,\ \Delta R_x / R \ll 1$$

$$(u\ praksi\ \Delta R_x / R = 5\%)$$

$$u_{AB} = u_{AD} + u_{DB} = -E \cdot \frac{R_2}{R_1 + R_2} + E \cdot \frac{R_x}{R_x + R_3} = E \cdot \frac{R_x R_1 - R_2 R_3}{(R_1 + R_2)(R_x + R_3)}$$

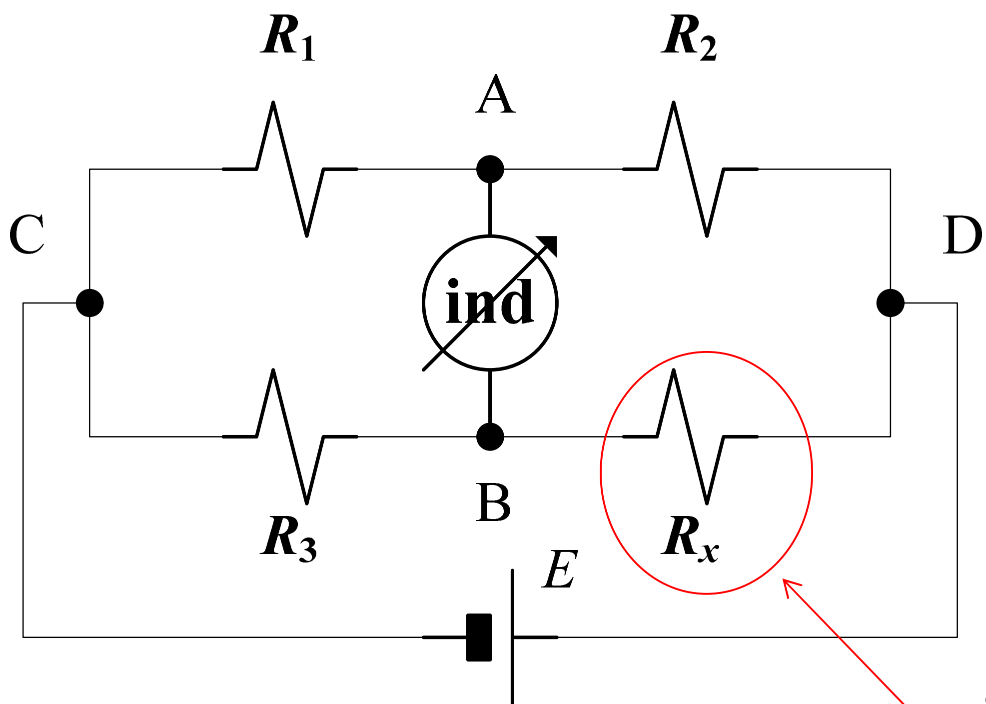
$$u_{AB} = E \cdot \frac{(R + \Delta R_x)R - R^2}{2R(R + \Delta R_x + R)} = E \cdot \frac{\Delta R_x}{2R\left(2 + \frac{\Delta R_x}{R}\right)} \approx E \cdot \frac{\Delta R_x}{4R}$$

$$\Rightarrow \Delta R_x = \frac{4R}{E} \cdot u_{AB}$$

Merni opseg za merenja neuravnoteženim Vitstonovim mostom je: $R \pm \Delta R_x$

MERENJE OTPORNOSTI MOSTOM

Vitstonov most – neuravnoteženi - PRIMENA



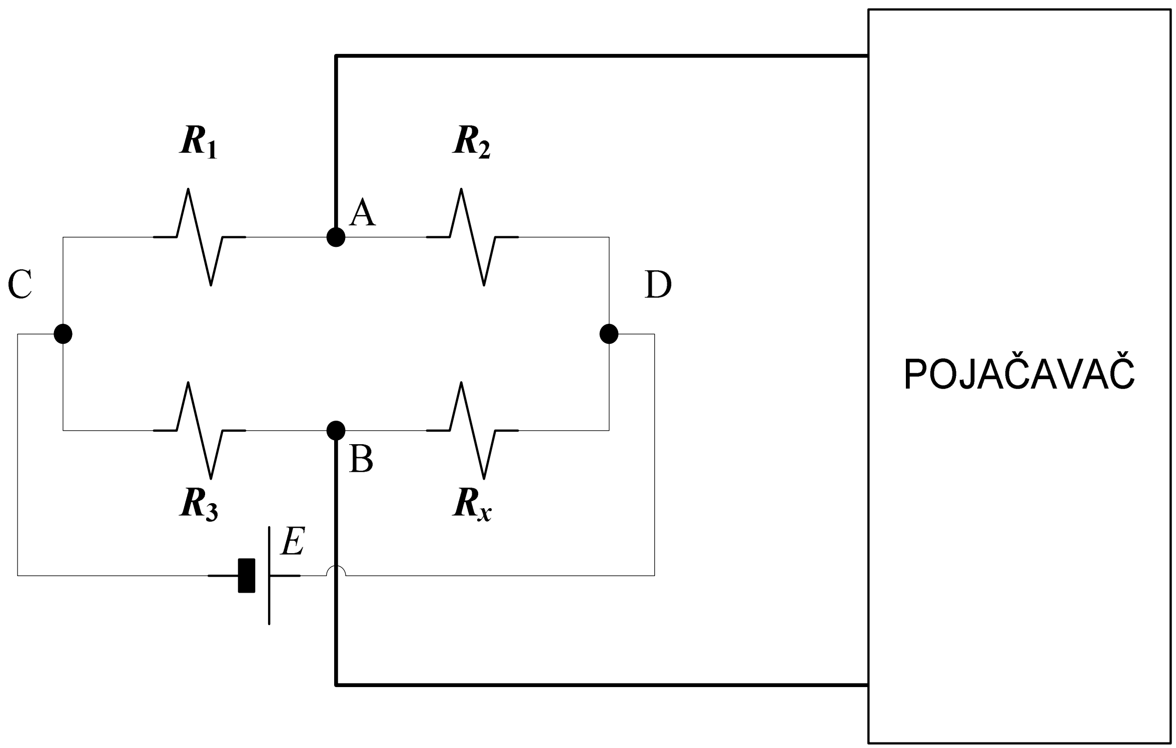
$$\Delta R_x = \frac{4R}{E} \cdot u_{AB}$$

Senzor
(pretvarač neelektrične veličine u otpornost)

Lab. vežba: upotreba NTC termistora kao senzora temperature

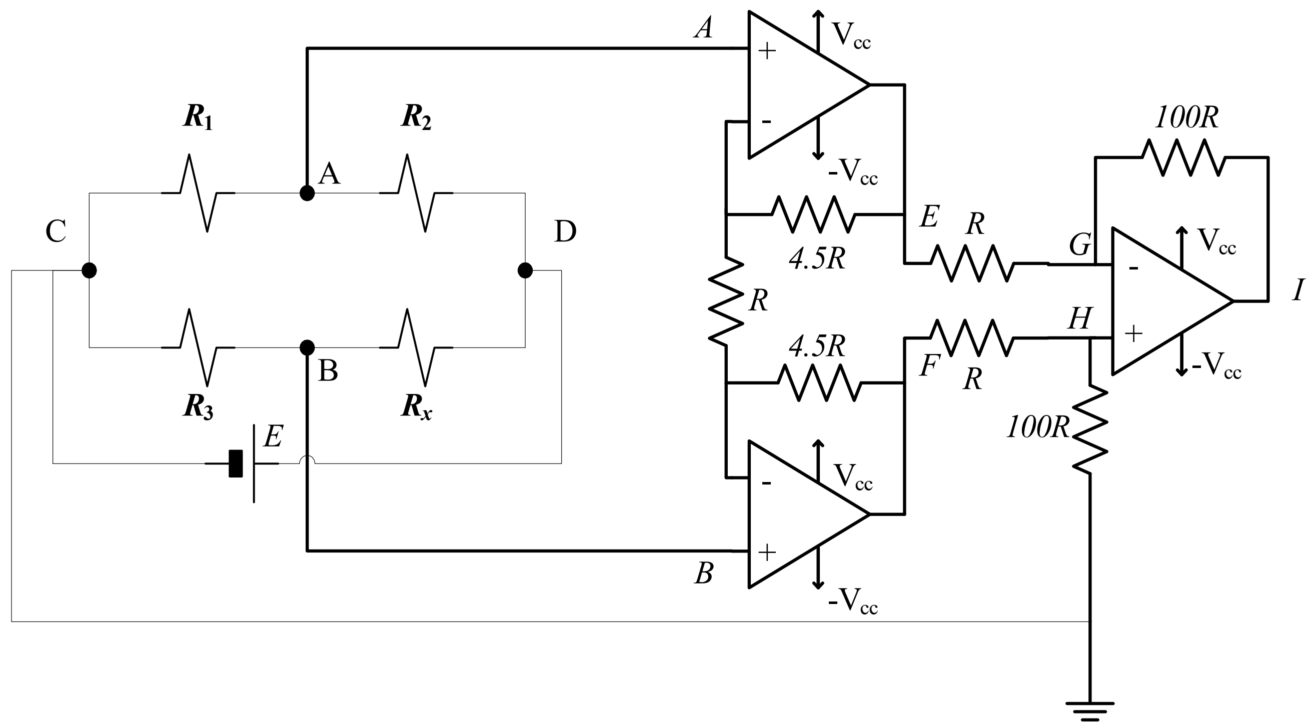
MERENJE OTPORNOSTI MOSTOM

Vitstonov most – neuravnoteženi - PRIMENA



u_{AB} **je obično neophodno pojačati pre merenja!**

Primer

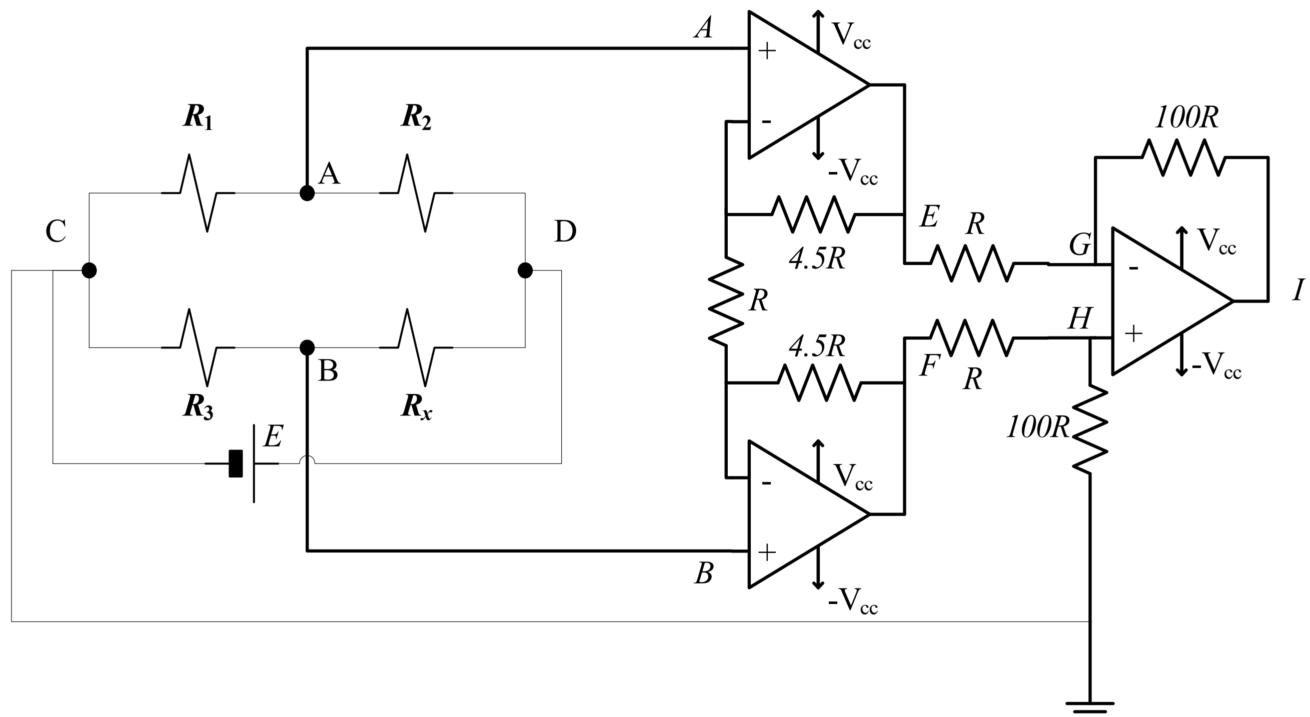


Na slici je prikazan neuravnotežen Vitstonov most čiji izlazni napon u_{AB} se vodi na instrumentacioni pojačavač. Smatrati da je indikator idealan voltmetar. R_x je promenljiva otpornost. Poznato je:

$$R_1 = R_2 = R_3 = R$$
$$R_x = R + \Delta R_x, \ \Delta R_x / R \ll 1$$

Odrediti vrednost izlaznog napona pojačavača v_i u funkciji elemenata kola.

Primer



Na slici je prikazan **neuravnotežen** **Vitstonov most čiji izlazni napon u_{AB} se vodi na instrumentacioni pojačavač. Smatrati da je indikator idealan voltmetar. R_x je promenljiva otpornost. Poznato je:**

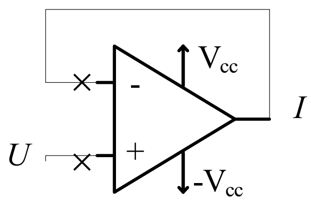
$$R_1 = R_2 = R_3 = R$$
$$R_x = R + \Delta R_x,\ \Delta R_x / R << 1$$

Odrediti vrednost izlaznog napona pojačavača v_i u funkciji od R, E i ΔR_x.

Na prethodnim stranicama je izveden izraz: $u_{AB} \approx E \cdot \dfrac{\Delta R_x}{4R}$

Primer

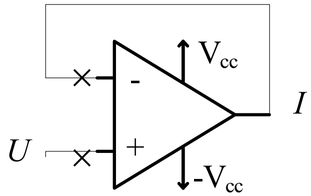
Digresija:



$\Rightarrow$ **v_I = ?**

Primer

Digresija:



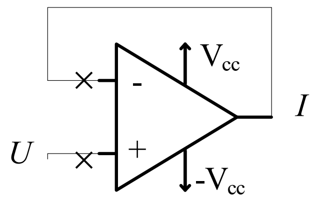
Linearni režim rada operacionog pojačavača:

- **ulazna struja je nula**
- $v^{+} = v^{-}$

$$v_I = \begin{cases} v_U, & -V_{cc} < v_U < V_{cc} \\ V_{cc}, & v_U \geq V_{cc} \\ -V_{cc}, & v_U \leq -V_{cc} \end{cases}$$

Primer

Digresija:



Linearni režim rada operacionog pojačavača:

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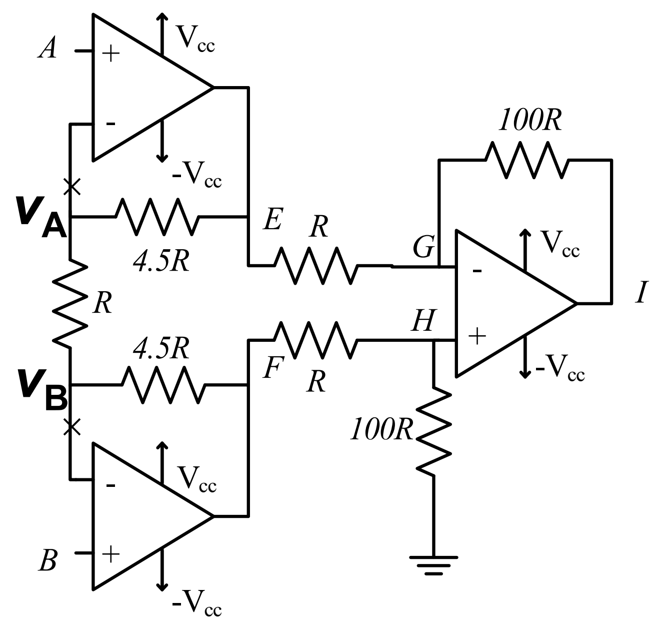
$$v_I = \begin{cases} v_U, & -V_{cc} < v_U < V_{cc} \\ V_{cc}, & v_U \geq V_{cc} \\ -V_{cc}, & v_U \leq -V_{cc} \end{cases}$$

$$\frac{v_I - v_G}{100R} = \frac{v_G - v_E}{R}$$

$$v_I = 101 v_G - 100 v_E = 101 v_H - 100 v_E$$

$$v_I = 101 v_F \frac{100R}{R + 100R} - 100 v_E$$

$$v_I = 100(v_F - v_E)$$

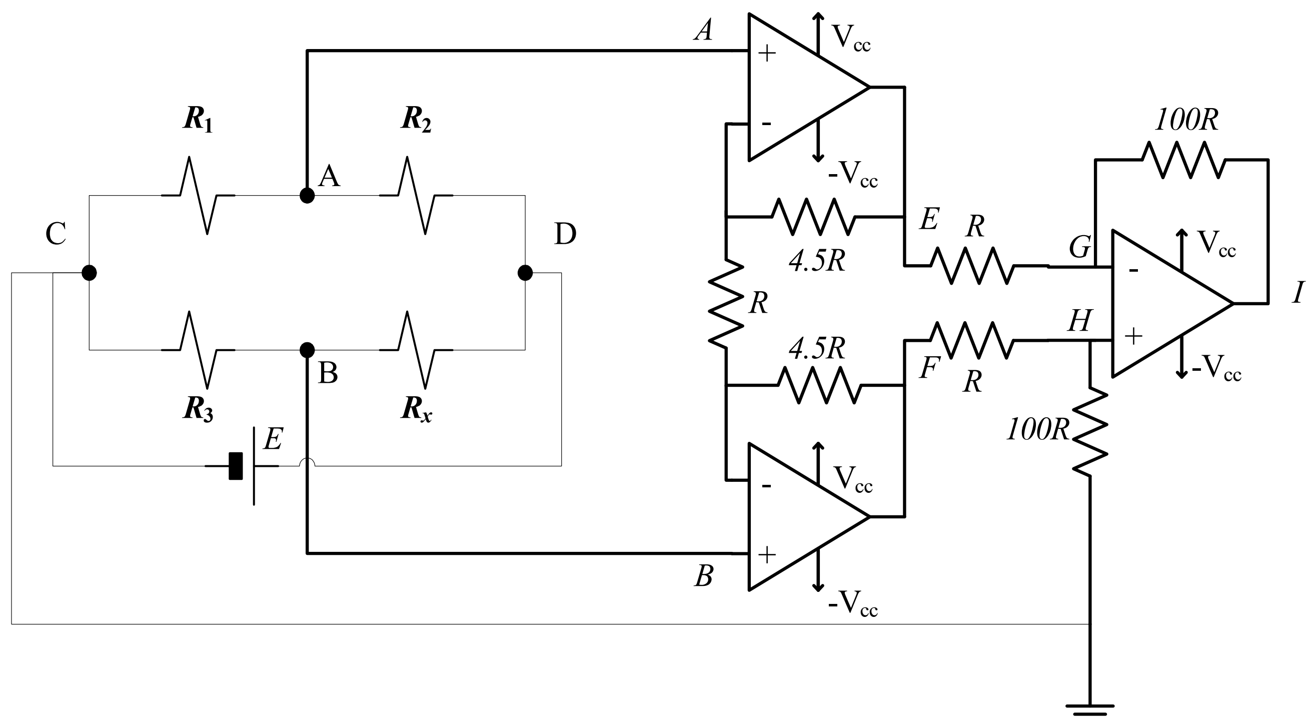


$$\frac{v_E - v_F}{10R} = \frac{v_A - v_B}{R}$$

$$v_E - v_F = 10(v_A - v_B)$$

$$v_I = -100 \cdot 10(v_A - v_B) = -1000 \cdot u_{AB} \approx -1000E \cdot \frac{\Delta R_x}{4R}$$

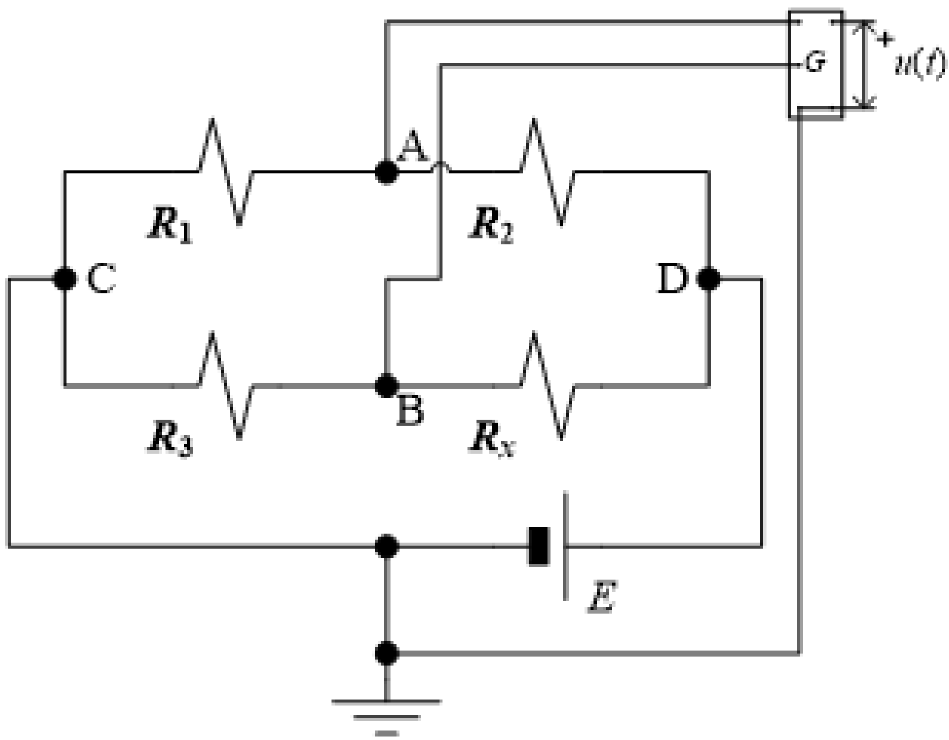
Primer



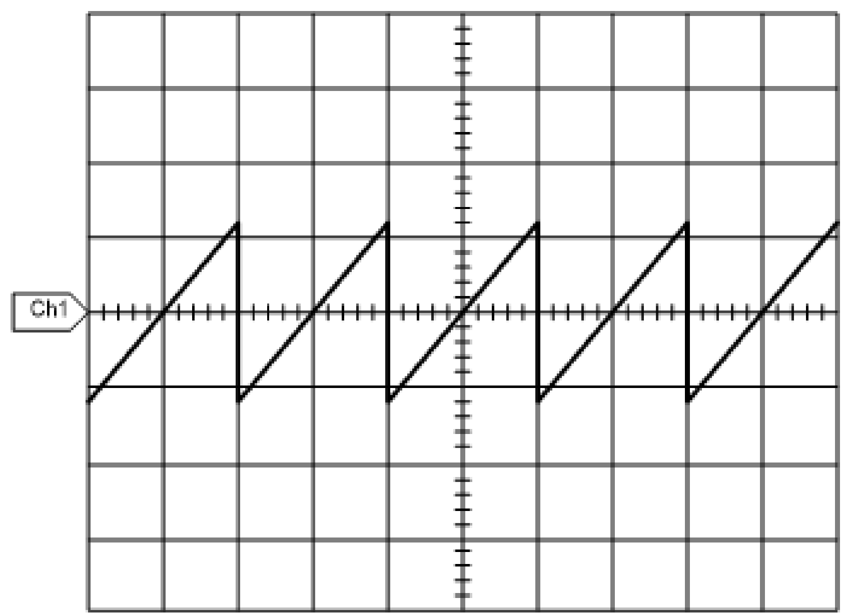
$$v_I = \begin{cases} -1000E \cdot \dfrac{\Delta R_x}{4R}, & -V_{cc} < -1000E \cdot \dfrac{\Delta R_x}{4R} < V_{cc} \\ V_{cc}, & -1000E \cdot \dfrac{\Delta R_x}{4R} \geq V_{cc} \\ -V_{cc}, & -1000E \cdot \dfrac{\Delta R_x}{4R} \leq -V_{cc} \end{cases}$$

februar 2017

4. Na Sl. 4 je prikazan neuravnotežen Vitstonov most sa diferencijalnim pojačavačem pojačanja G=100 za merenje električne otpornosti R_x. Za merenje napona $u(t)=G{\cdot}u_{AB}(t)$ na izlazu pojačavača se koristi osciloskop.
a) Odrediti izraz za napon u_{AB} u funkciji vrednosti otpornika R_1, R_2, R_3 i R_x.
b) Ako je R_x promenljivo i napon $u(t)$ ima oblik kao napon na kanalu 1 osciloskopa, Sl. 1, nacrtati grafik $R_x(t)$ za: E=12 V, $R_1=R_2=R_3=R$=100 Ω i $R_x=R+\Delta R_x$ (uzeti u obzir da je $\Delta R_x/R$<<1).
c) Na koji način bi trebalo povezati osciloskop ako bi se direktno merio napon u_{AB}?

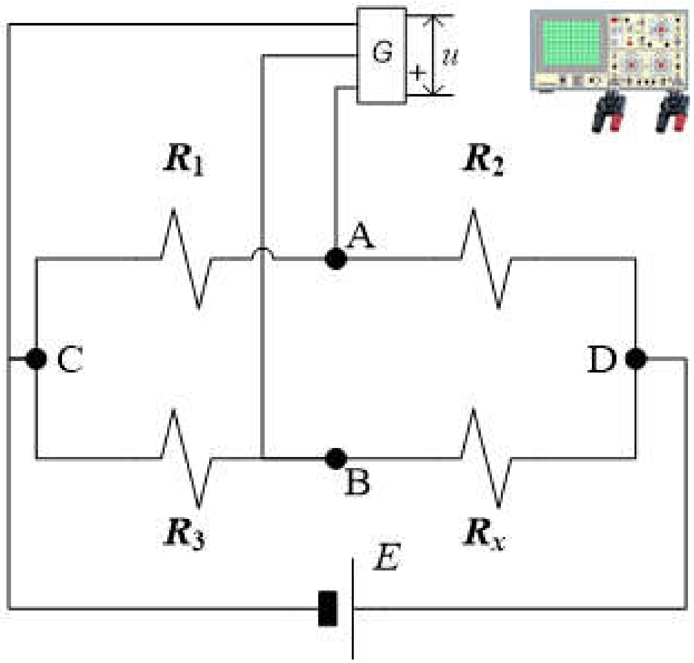


Sl. 4.

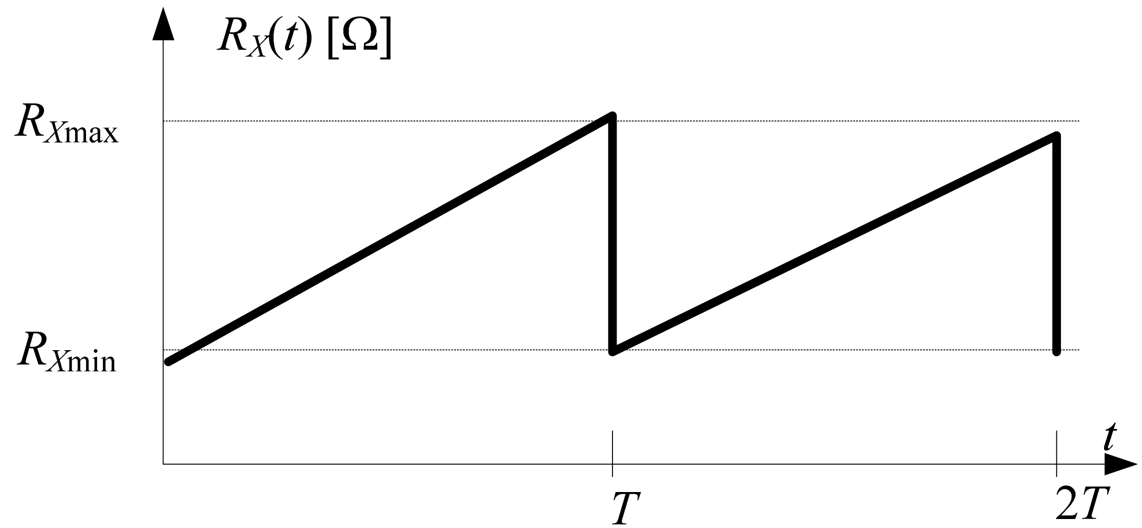


Sl. 1.

k_y=2V/div



Sl. 4.1



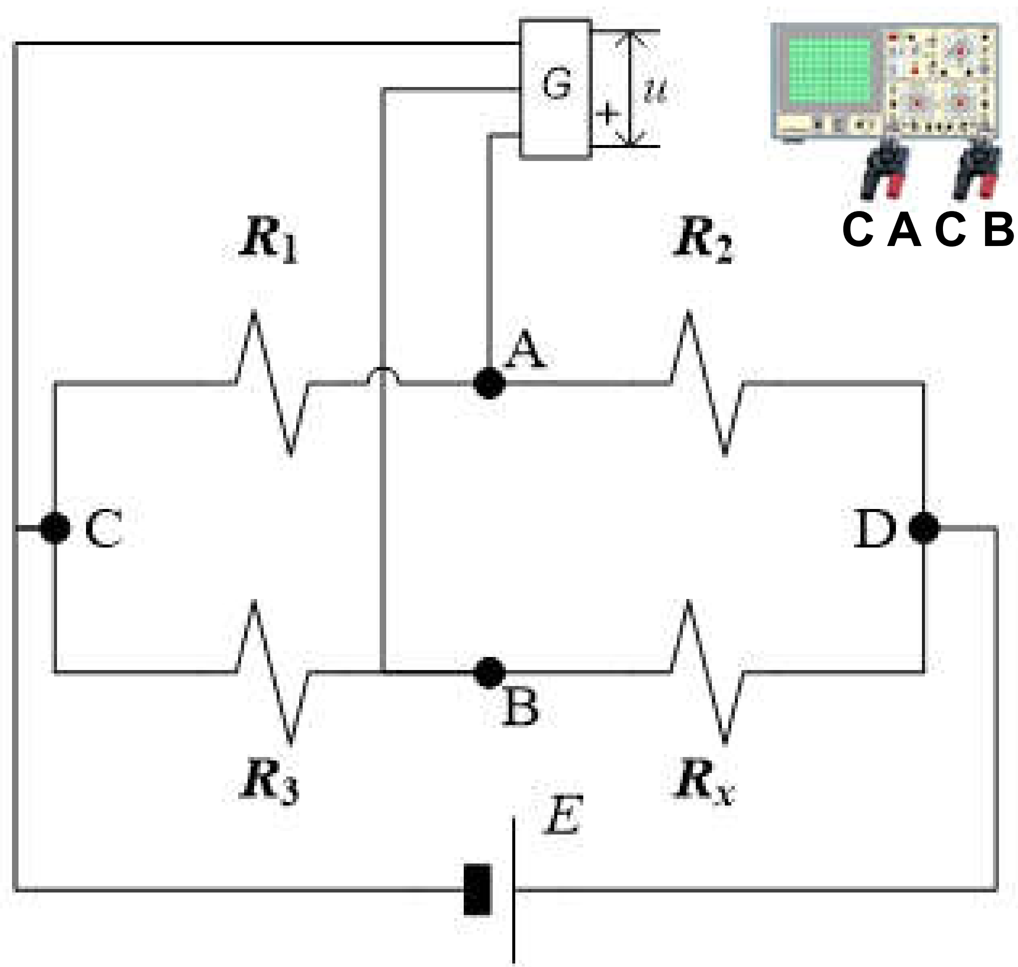
a) $$u_{AB} = u_{AD} + u_{DB} = -E \cdot \frac{R_2}{R_1 + R_2} + E \cdot \frac{R_x}{R_x + R_3} = E \cdot \frac{R_x R_1 - R_2 R_3}{(R_1 + R_2)(R_x + R_3)}$$

b) $$u_{AB} = E \cdot \frac{(R + \Delta R_x)R - R^2}{2R(R + \Delta R_x + R)} = E \cdot \frac{\Delta R_x}{2R\left(2 + \frac{\Delta R_x}{R}\right)} \approx E \cdot \frac{\Delta R_x}{4R}$$

$$R_x(t) = R + \Delta R_x(t) = R \cdot \left(1 + \frac{4u_{AB}(t)}{E}\right) = R \cdot \left(1 + \frac{4u(t)}{GE}\right)$$

$$R_{x\max} = 100.8\,\Omega, \qquad R_{x\min} = 99.2\,\Omega$$

c)

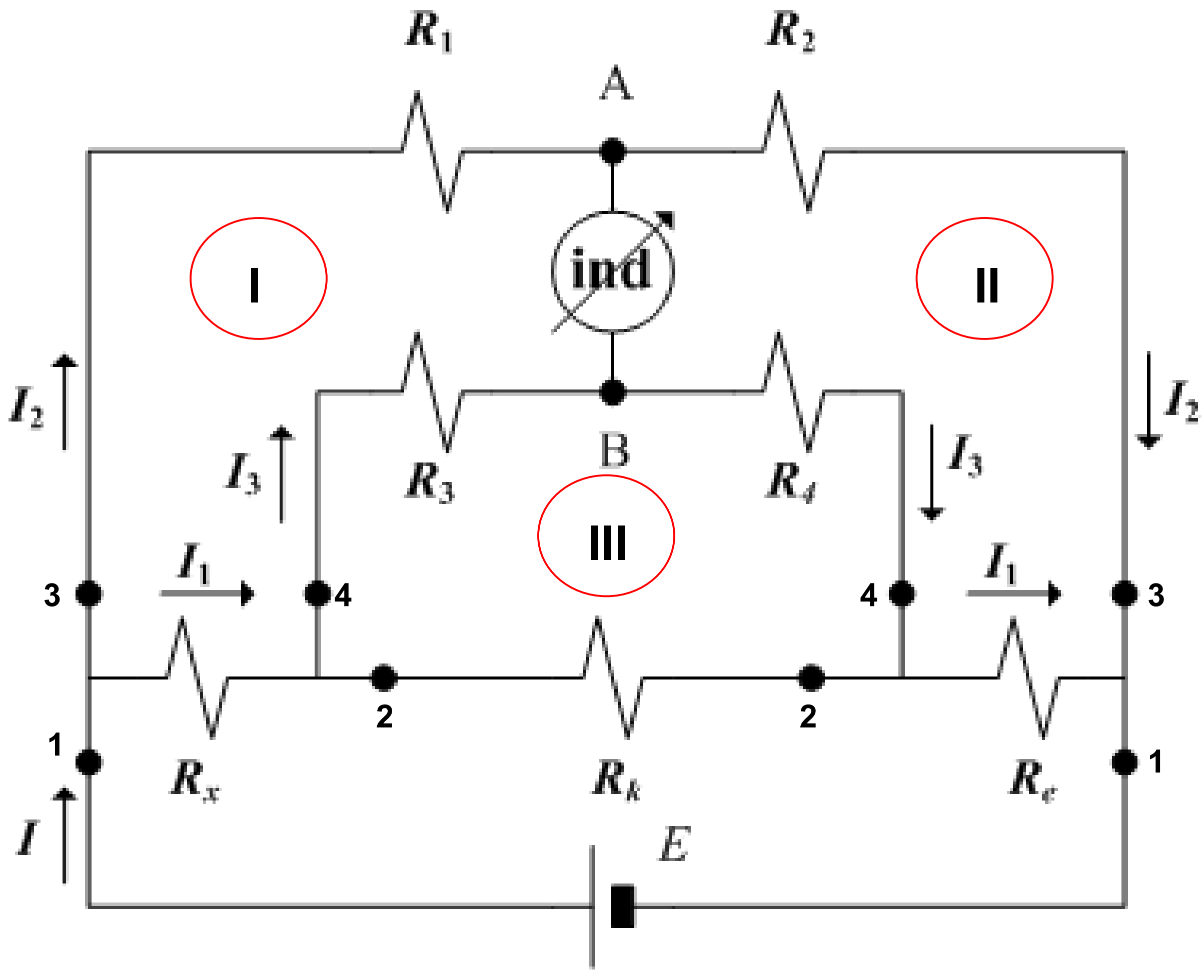


Sl. 4.

CH1+: tačka A, CH1-: tačka C, CH2+: tačka B, CH2-: tačka C
Invertovati kanal 2 (*Invert*) i izabrati opciju za sabiranje kanala (*ADD*).

MERENJE OTPORNOSTI MOSTOM

Kelvinov (ili Tomsonov) most



Kelvinov otpornik
(otpornik sa 4 pristupa)
1,2 – strujni pristupi
3,4 – naponski pristupi

$$I \qquad I_2 R_1 = I_1 R_x + I_3 R_3$$

$$II \qquad I_2 R_2 = I_1 R_e + I_3 R_4$$

$$III \qquad I_3 (R_4 + R_3) = (I_1 - I_3) R_k$$

$$R_x = R_e \frac{R_1}{R_2} + \frac{R_k (R_1 R_4 - R_2 R_3)}{R_2 (R_3 + R_4 + R_k)}$$

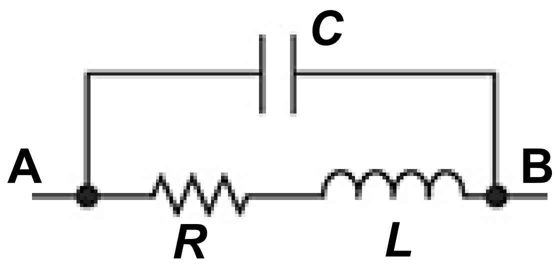
$$Ako\ je: \quad R_1 R_4 = R_2 R_3$$

$$R_x = R_e \frac{R_1}{R_2}$$

***R*$_k$ - otpornost mernih vodova i kontakata**
***R*$_e$ - etalonski otpornik**

Merni opseg (male otpornosti): od 1 μΩ do 1 Ω.

EKVIVALENTAN MODEL OTPORNOSTI



Ekvivalentna šema realnog otpornika

$$\underline{Z}_{AB} = R_{ekv} + jX_{ekv}$$

$$\underline{Z}_{AB} = \frac{R + j\omega\left[L\left(1-\omega^2 LC\right) - R^2 C\right]}{\left(1-\omega^2 LC\right)^2 + \left(\omega RC\right)^2}$$

Niska učestanost

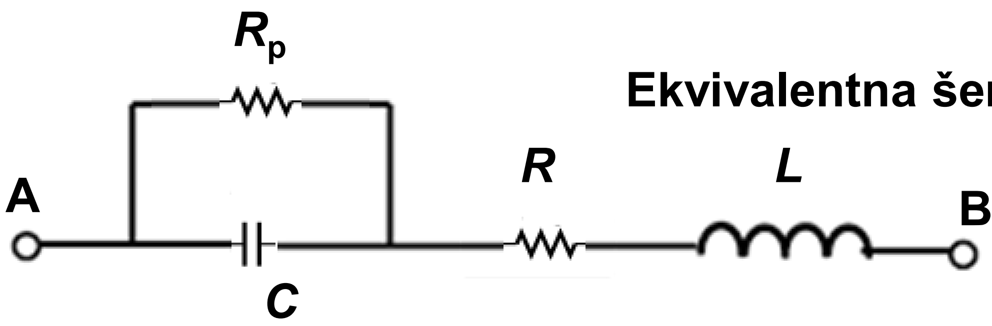
$$Kada\ je\quad 1-\omega^2 LC \approx 1 \quad i \quad 1+\left(\omega RC\right)^2 \approx 1:$$

$$\underline{Z}_{AB} = R + j\omega\left[L - R^2 C\right]$$

$$Za\ malo\ R: \quad \underline{Z}_{AB} \approx R + j\omega L$$

$$Za\ veliko\ R: \quad \underline{Z}_{AB} \approx R - j\omega R^2 C$$

EKVIVALENTAN MODEL KAPACITIVNOSTI



Ekvivalentna šema realnog kondenzatora

R **– otpornost metalnih delova kondenzatora**
L – induktivnost provodnika i elektroda
***R*p – dielektrični gubici**

$$\underline{Z}_{AB} = R + j\omega L + \frac{R_p}{1 + j\omega C R_p}$$

$$\underline{Z}_{AB} = R + j\omega L + \frac{R_p - j\omega C R_p^2}{1 + (\omega C R_p)^2}$$

$$Važi: \quad 1 + (\omega C R_p)^2 \approx (\omega C R_p)^2$$

$$\underline{Z}_{AB} = R + j\omega L + \frac{R_p - j\omega C R_p^2}{(\omega C R_p)^2}$$

$$\underline{Z}_{AB} = R + \frac{1}{\omega^2 C^2 R_p} + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\underline{Z}_{AB} = R_{ekv} + jX_{ekv}$$

$$R_{ekv} = R + \frac{1}{\omega^2 C^2 R_p}, \quad X_{ekv} = \omega L - \frac{1}{\omega C}$$

$$X_{ekv} = 0 \quad za \quad \omega = \omega_0 = 1/\sqrt{LC} \quad (rezonancija\ kola)$$

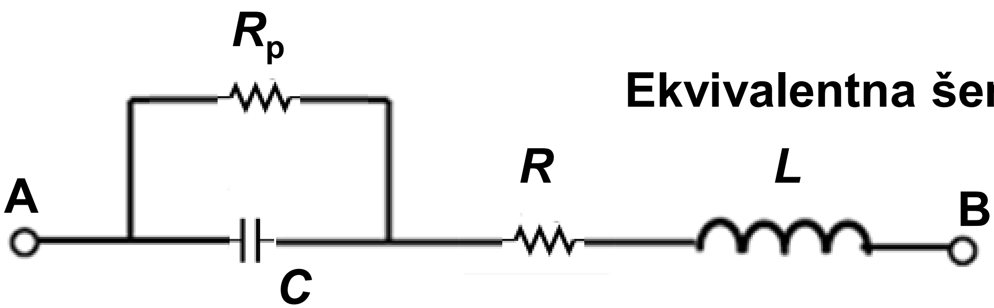
Za $\omega = \omega_0$ $\underline{Z}_{AB} = R_{ekv}$

Za $\omega > \omega_0$ *induktivna komponenta je* dominantna

Za $\omega < \omega_0$ *kapacitivna komponenta je* dominantna

EKVIVALENTAN MODEL KAPACITIVNOSTI

Ekvivalentna šema realnog kondenzatora



R **– otpornost metalnih delova kondenzatora**
L – induktivnost provodnika i elektroda
***R*p** **– dielektrični gubici**

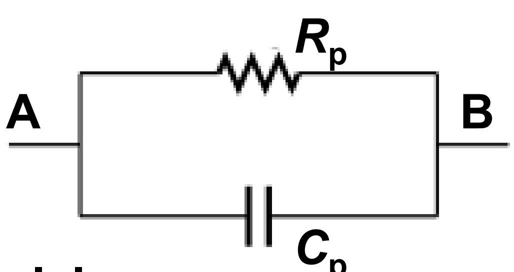
$$\underline{Z}_{AB} = R_{ekv} + jX_{ekv}$$

$$R_{ekv} = R + \frac{1}{\omega^2 C^2 R_p}, \quad X_{ekv} = \omega L - \frac{1}{\omega C}$$

Za $\omega < \omega_0$ *kapacitivna komponenta je* dominantna

uprošćeni modeli kapacitivnosti

Dobar izbor u slučaju velike reaktanse



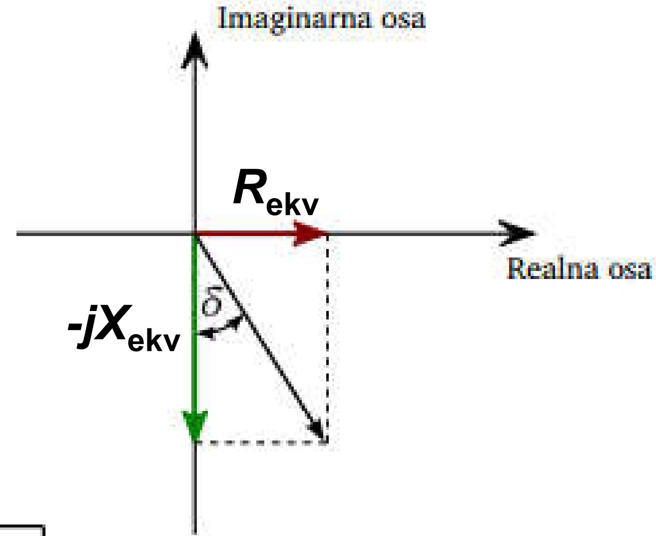
paralelna veza

Dobar izbor u slučaju male reaktanse

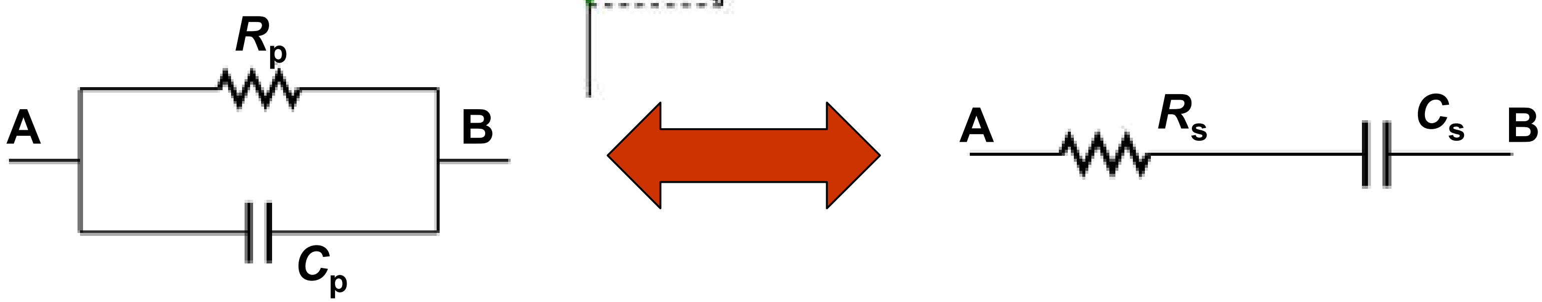
redna veza

EKVIVALENTAN MODEL KAPACITIVNOSTI

Faktor disipacije (tangens ugla gubitaka) se definiše kao: $tg\delta = \dfrac{R_{ekv}}{X_{ekv}}$



$$\underline{Z}_{AB} = R_{ekv} - jX_{ekv}$$



paralelna veza

redna veza

$$\underline{Z}_{AB} = \frac{R_p \dfrac{j}{\omega C_p}}{R_p + \dfrac{j}{\omega C_p}} = \underbrace{\frac{R_p}{1+(\omega C_p R_p)^2}}_{R_{ekv}} - j\underbrace{\frac{\omega C_p R_p^2}{1+(\omega C_p R_p)^2}}_{X_{ekv}}$$

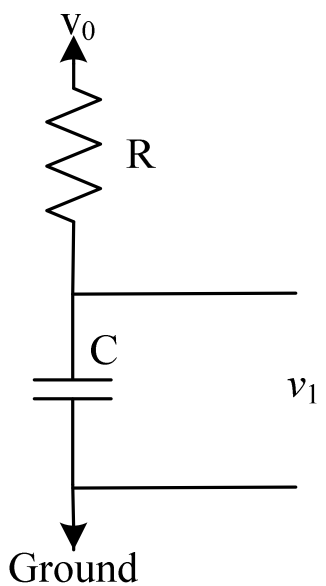
$$tg\delta = \frac{R_{ekv}}{X_{ekv}} = \frac{1}{\omega C_p R_p}$$

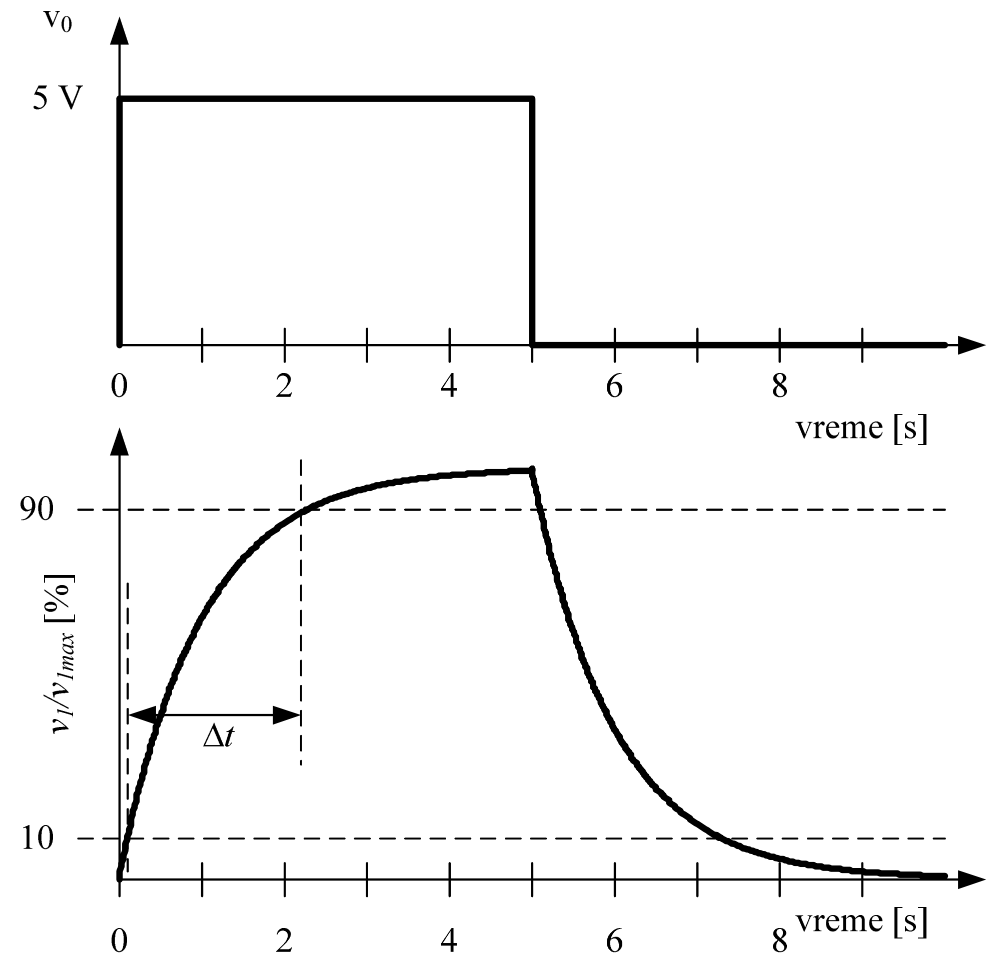
$$\underline{Z}_{AB} = R_s - j\frac{1}{\omega C_s}$$

$$R_{ekv} = R_s \qquad X_{ekv} = \frac{1}{\omega C_s}$$

$$tg\delta = \frac{R_{ekv}}{X_{ekv}} = \omega C_s R_s$$

ODZIV KONDENZATORA NA IMPULSNU POBUDU (lab. vežba)





$$v_1 = v_0\left(1 - e^{-\frac{t}{\tau}}\right), \qquad 0 < t < 5\,\text{s}$$

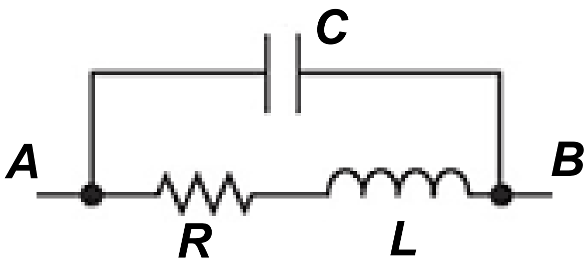
$$v_1 = v_0 e^{-\frac{t-T}{\tau}}, \qquad 5\,\text{s} \le t < 10\,\text{s},\ T = 5\,\text{s}$$

$$v_1 = 0, \qquad t > 10\,\text{s}$$

$$C = \frac{\Delta t}{R \ln 9} = \frac{t_{90} - t_{10}}{R \ln 9}$$

Procena kapacitivnosti na osnovu merenja trajanja uzlazne ivice

EKVIVALENTAN MODEL KALEMA



Ekvivalentna šema realnog kalema

$$\underline{Z}_{AB} = R_{ekv} + jX_{ekv}$$

$$\underline{Z}_{AB} = \frac{R + j\omega\left[L\left(1-\omega^2 LC\right) - R^2 C\right]}{\left(1-\omega^2 LC\right)^2 + \left(\omega RC\right)^2}$$

Kod kalemova se nastoji da R i C budu što manji, pa je:

$$Kada\ je \quad R^2 C << L(1-\omega^2 LC) \quad i \quad \left(\omega RC\right)^2 << (1-\omega^2 LC)^2 :$$

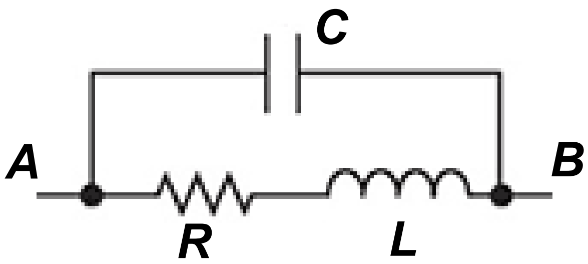
$$\underline{Z}_{AB} = \frac{R}{\left(1-\omega^2 LC\right)^2} + j\omega\frac{L}{1-\omega^2 LC} = R_{ekv} + jX_{ekv}$$

$$R_{ekv} = \frac{R}{\left(1-\omega^2 LC\right)^2} \qquad X_{ekv} = \omega\frac{L}{1-\omega^2 LC} = \omega L_{ekv}, \quad L_{ekv} = \frac{L}{1-\omega^2 LC}$$

$$f\uparrow \;\Rightarrow\; R_{ekv}\uparrow, L_{ekv}\uparrow \quad sve\ do\ f = f_0$$

$$f = f_0 = 1/2\pi\sqrt{LC} \quad rezonantna\ frekvencija$$

EKVIVALENTAN MODEL KALEMA

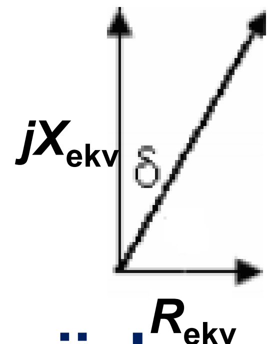


Ekvivalentna šema realnog kalema

$$R_{ekv} = \frac{R}{\left(1-\omega^2 LC\right)^2} \qquad X_{ekv} = \omega \frac{L}{1-\omega^2 LC}$$

Faktor dobrote realnog *kalema Q*

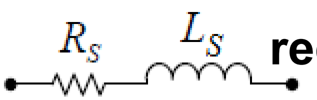
(*odnos* maksimalne *akumulisane energije prema disipiranoj energiji*):



$$Q = \frac{1}{tg\delta} = \frac{X_{ekv}}{R_{ekv}} = \frac{\omega L}{R}\left(1-\omega^2 LC\right)$$

Nelinearna funkcija frekvencije!

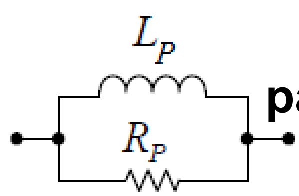
uprošćene šeme induktivnosti



redna veza

Dobar izbor u slučaju male reaktanse

$$Q = \frac{X_{ekv}}{R_{ekv}} = \frac{\omega L_s}{R_s}$$

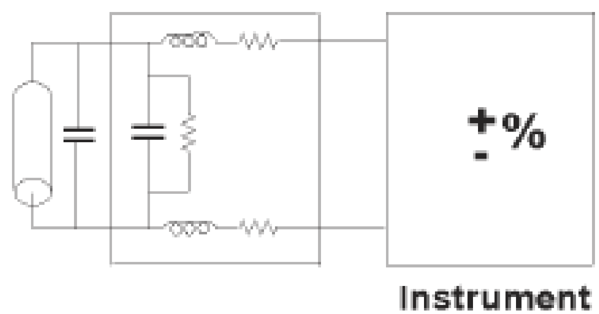


paralelna veza

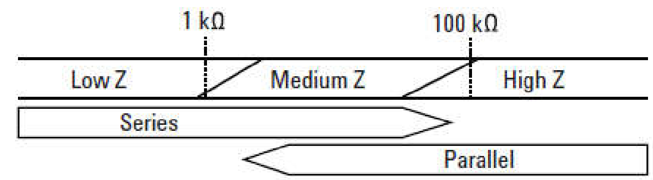
Dobar izbor u slučaju velike reaktanse

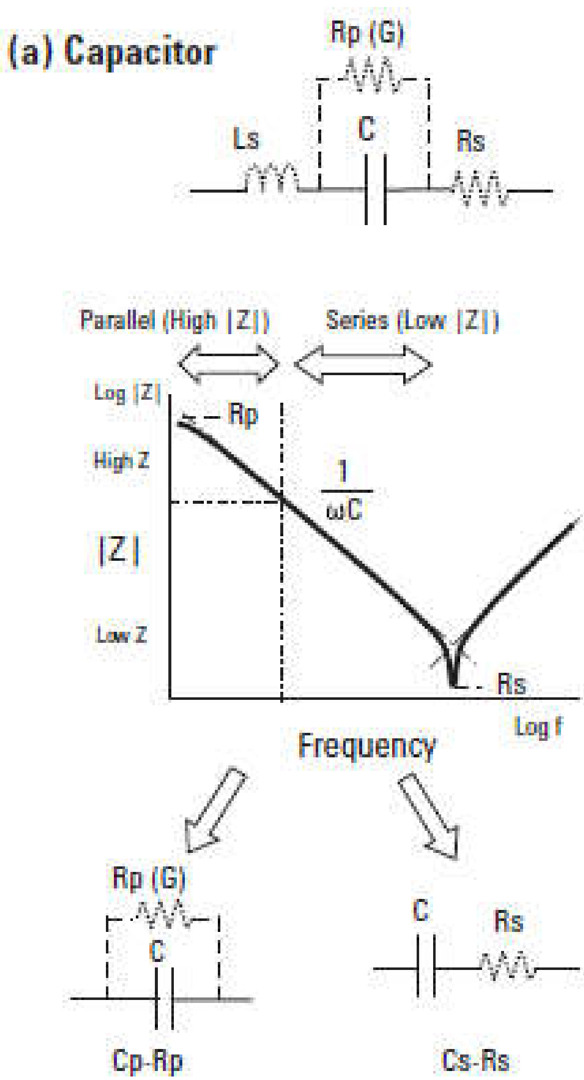
$$Q = \frac{X_{ekv}}{R_{ekv}} = \frac{R_p}{\omega L_p}$$

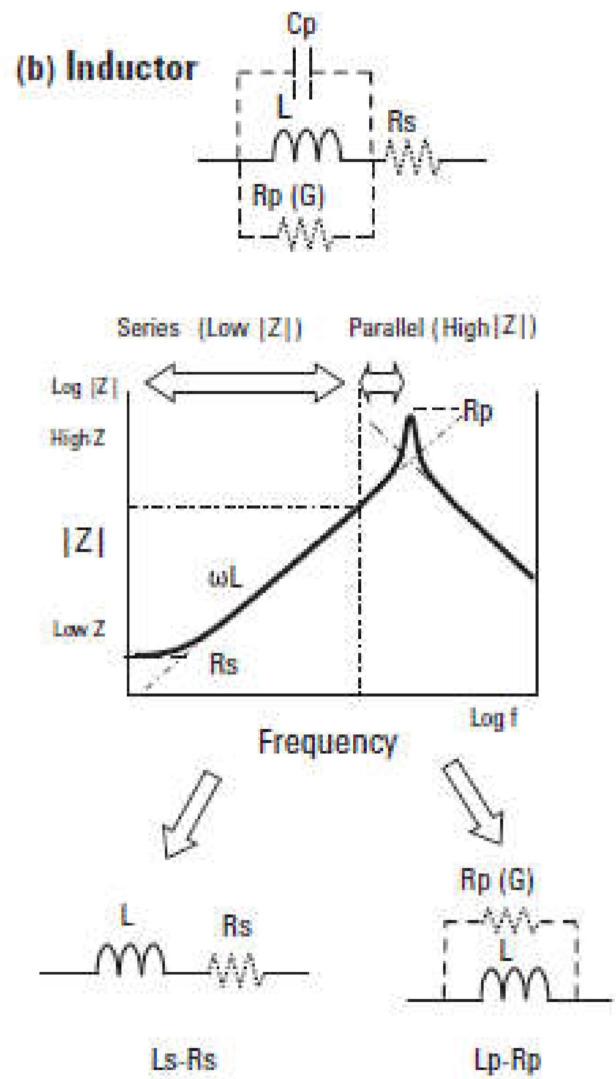
Merenje impedanse LRC metrom



LRC metar







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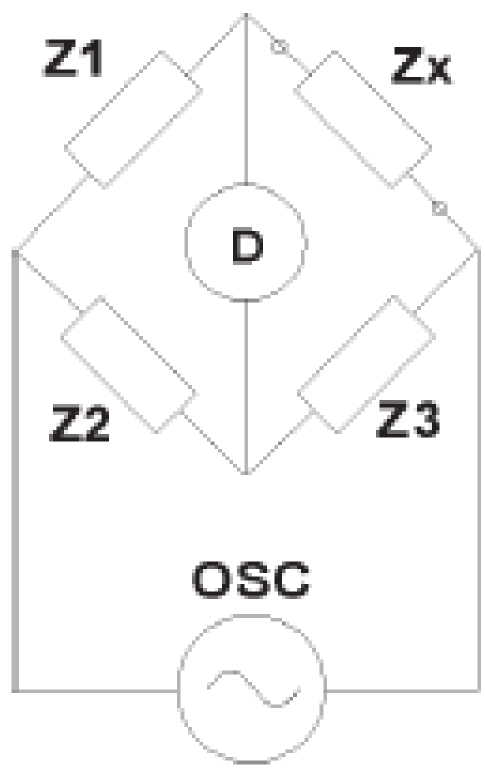
LRC metar – princip rada

- Merni most
- Rezonantni metod
- Merenje struje i napona
- Automatizovani most (autobalancing bridge)

LRC metar

Most za naizmeničnu struju



$$Zx = \frac{Z1}{Z2} Z3$$

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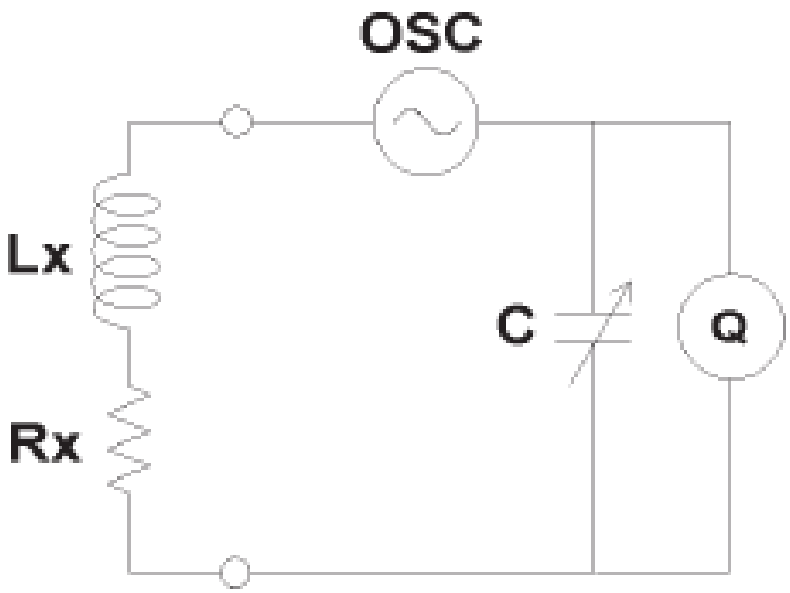
LRC metar
Rezonantni metod



frekvencija testiranja

C

Q

→ Lx, Rx

Podešavanjem C se kolo dovede u rezonanciju.

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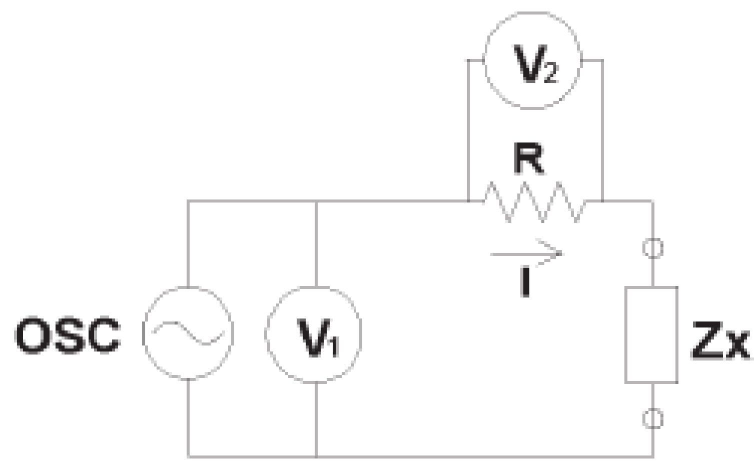
LRC metar

Merenje struje i napona



$$Zx = \frac{V_1}{I} = \frac{V_1}{V_2} R$$

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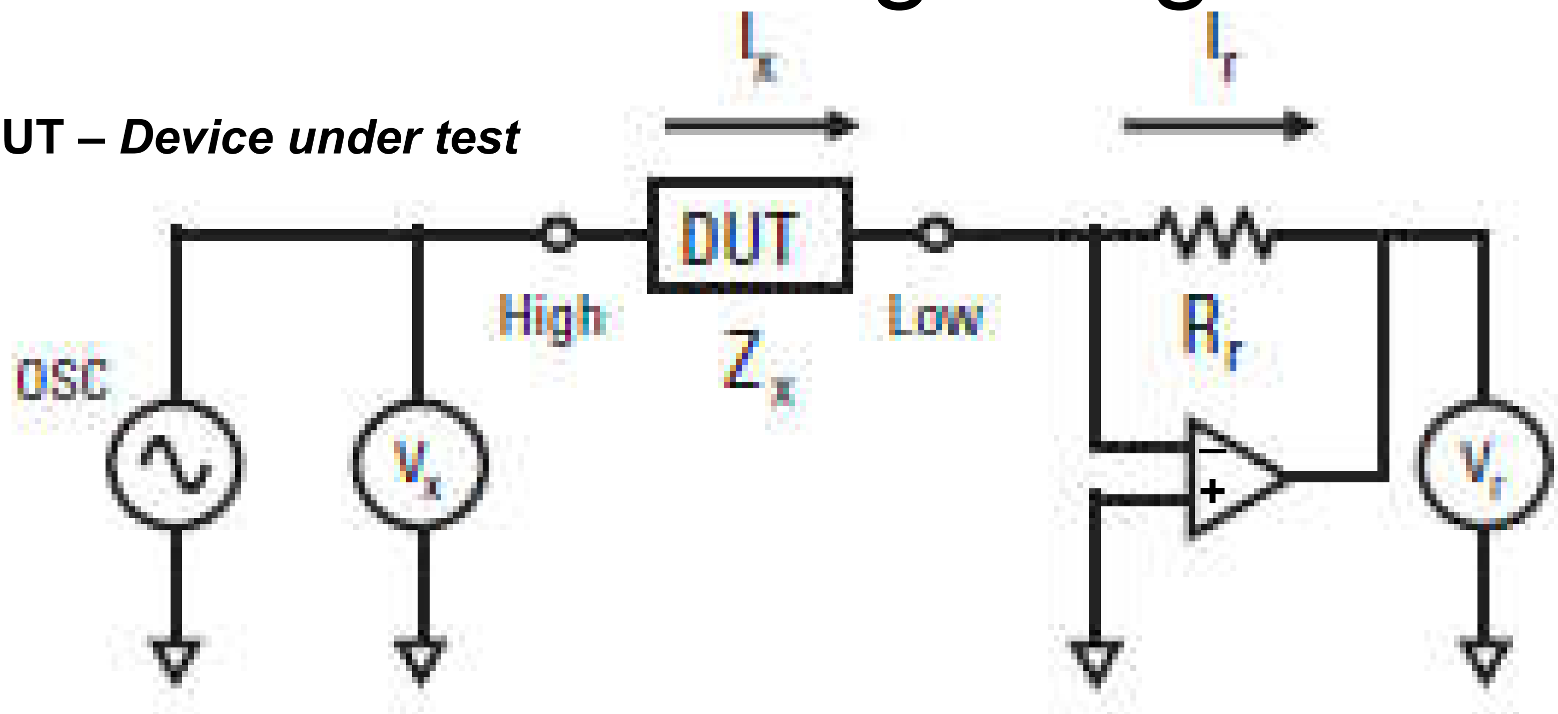
LRC metar

Autobalancing bridge

DUT – *Device under test*



$$\frac{V_x}{Z_x} = I_x = I_r = \frac{V_r}{R_r}$$

$$\longrightarrow Z_x = \frac{V_x}{I_x} = R_r \frac{V_x}{V_r}$$

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LRC metar

	Advantages	Disadvantages	Applicable frequency range	Agilent measurement instruments	Common applications
Bridge method	• High accuracy (0.1% typ.) • Wide frequency coverage by using different types of bridges • Low cost	• Needs to be manually balanced • Narrow frequency coverage with a single instrument	DC to 300 MHz	None	Standard lab
Resonant method	• Good Q accuracy up to high Q	• Needs to be tuned to resonance • Low impedance measurement accuracy	10 kHz to 70 MHz	None	High Q device measurement
I-V method	• Grounded device measurement • Suitable to probe-type test needs	• Operating frequency range is limited by transformer used in probe	10 kHz to 100 MHz	None	Grounded device measurement
Auto-balancing bridge method	• Wide frequency coverage from LF to HF • High accuracy over a wide impedance measurement range • Grounded device measurement	• Higher frequency ranges not available	20 Hz to 110 MHz	E4980A E4981A 4294A 4294A+42941A[1] 4294A+42942A[1]	Generic component measurement 1. Grounded device measurement

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