EMC in načrtovanje TIV

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Elektromagnetna združljivost

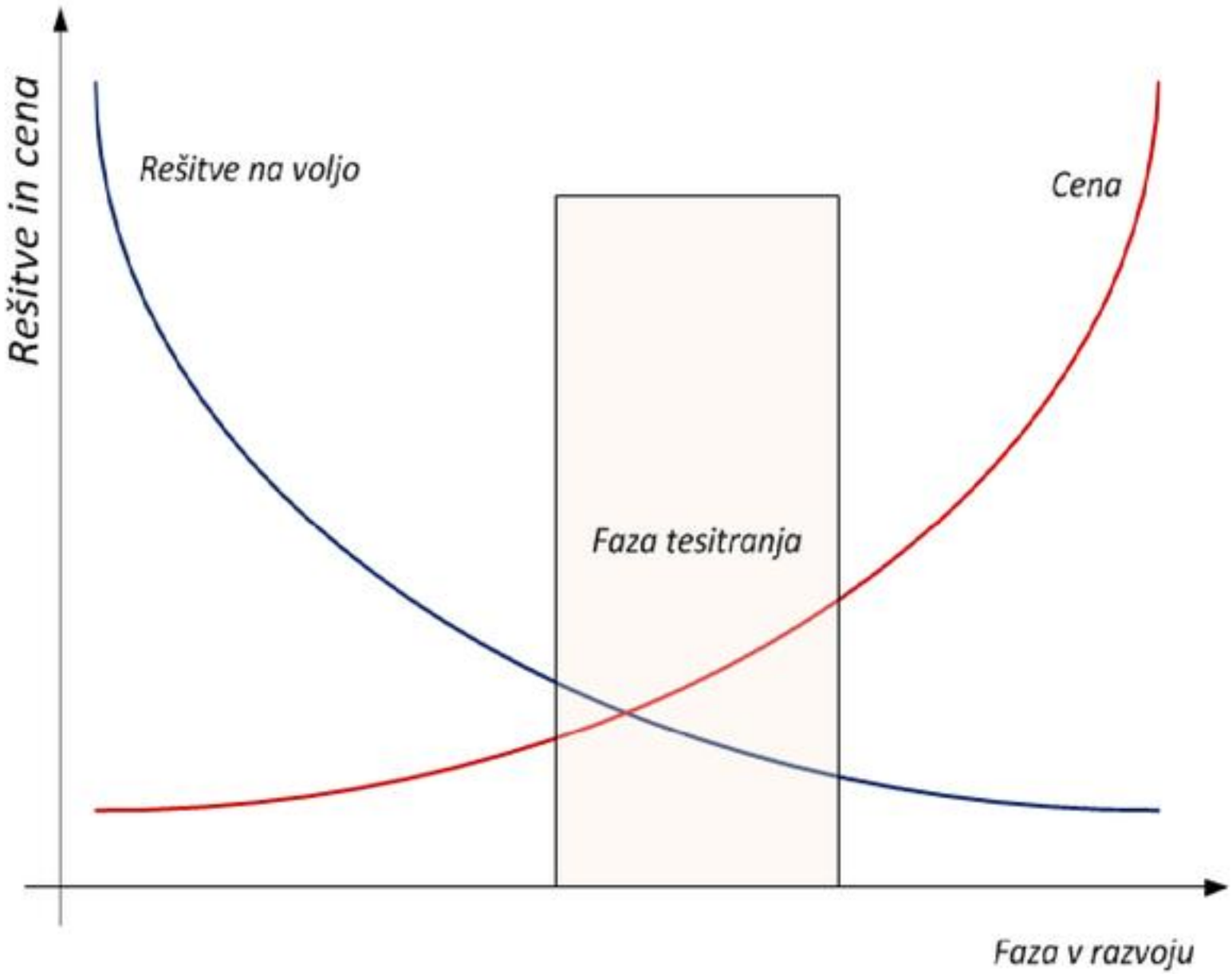
Motnja/ emisija

- Prevodna (Conducted)
- Sevalna (Radiated)

Odpornost/ imunost

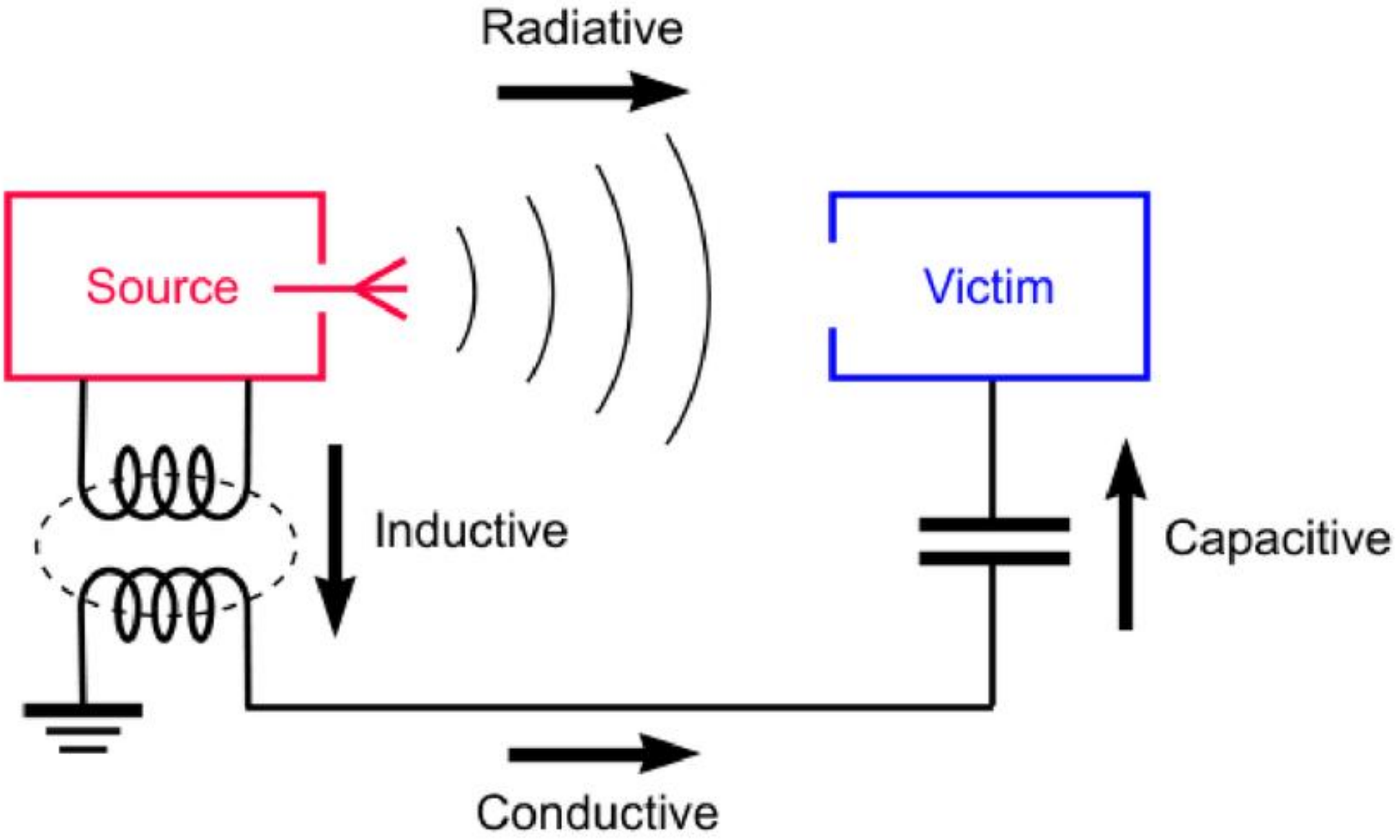
- Prevodna (Conducted)
- Elektrostatska razelektritev (ESD)
- Sevalna (Radiated)

Doseganje EMC

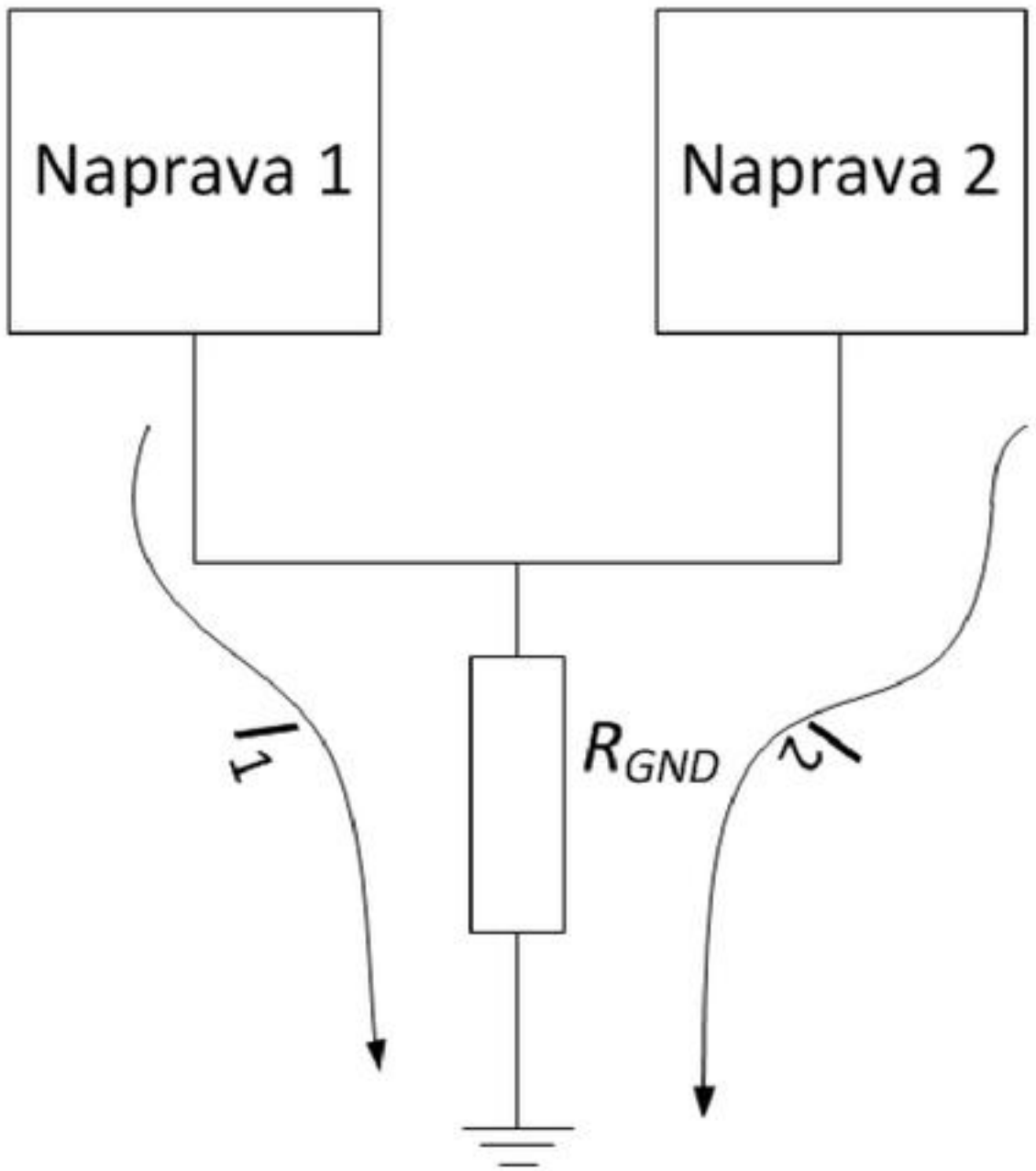


Model EMC

Povezave


Radiative
Source
Victim
Inductive
Capacitive
Conductive

Konduktivna povezava preko skupne mase

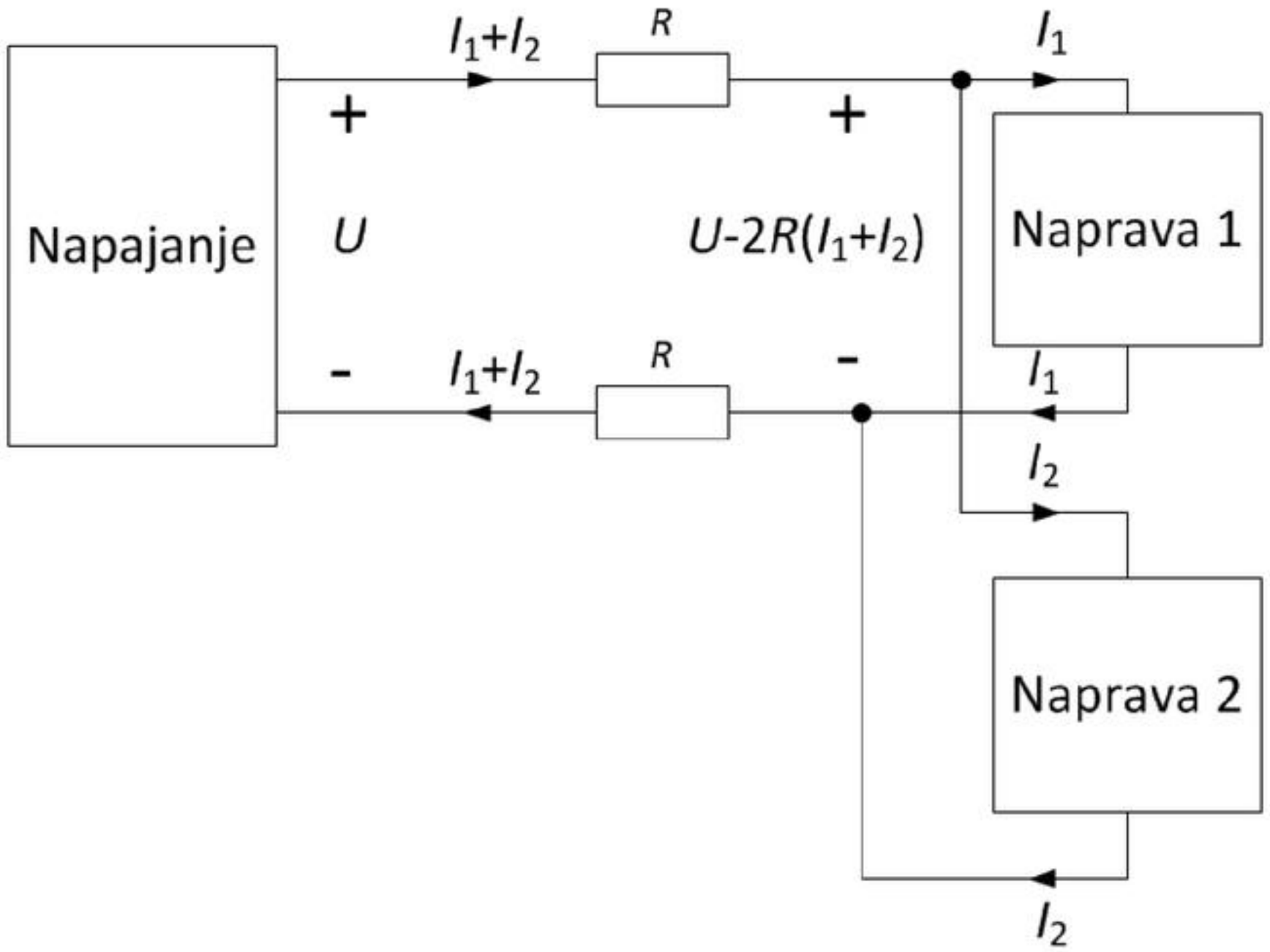


+

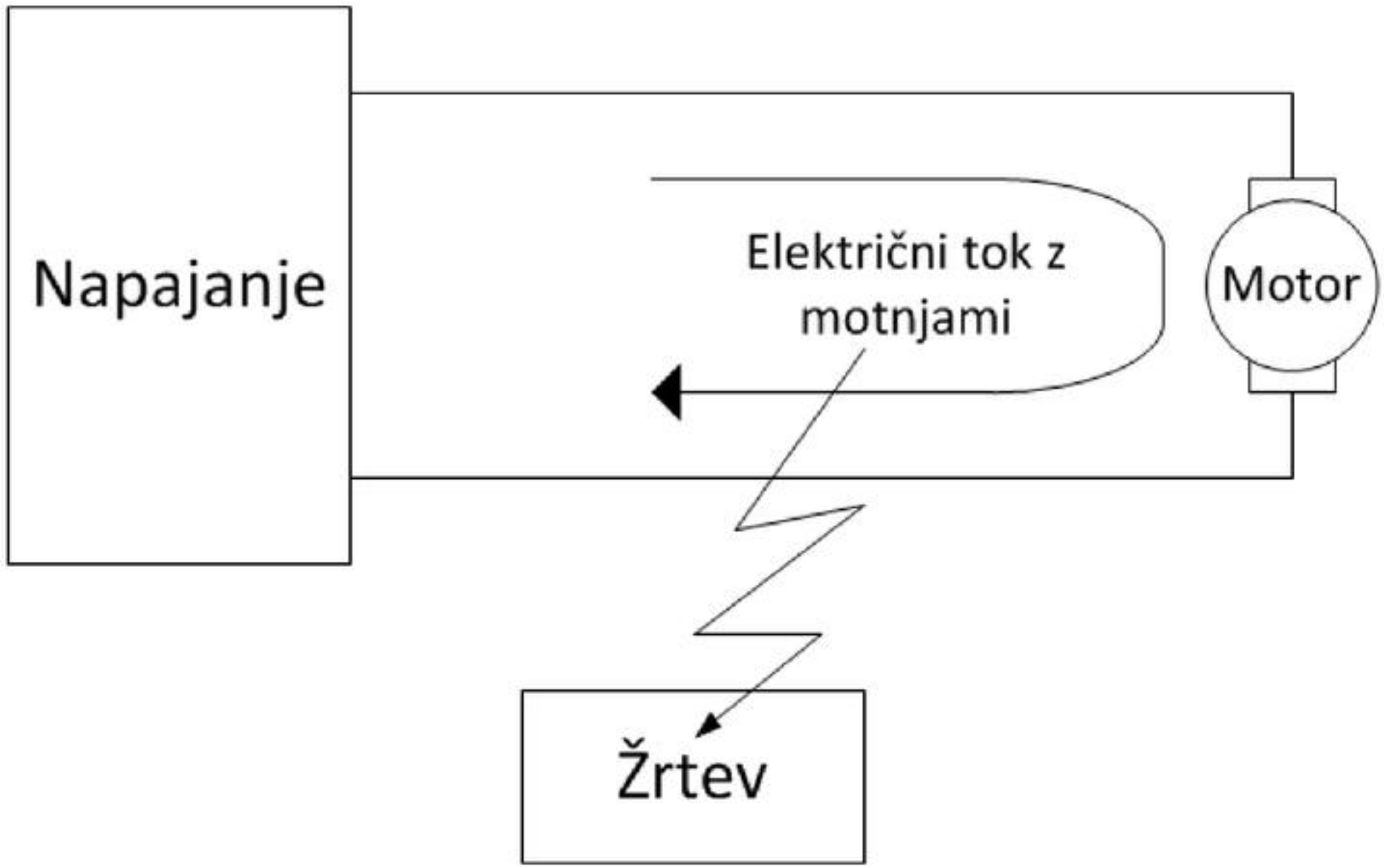
$U_{GND} = R_{GND} * (I_1+I_2)$

-

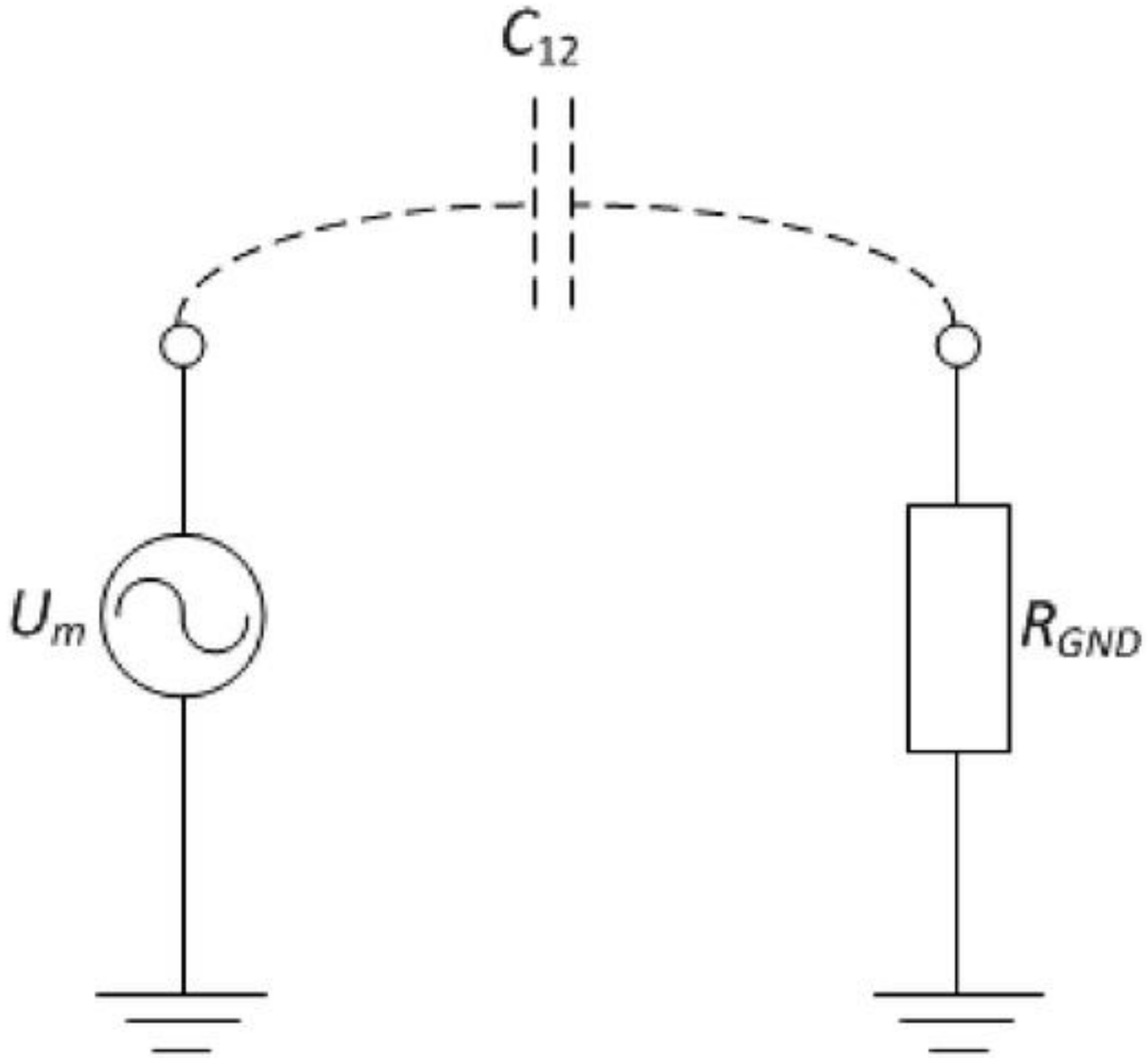
Konduktivna povezava prek napajalnih linij



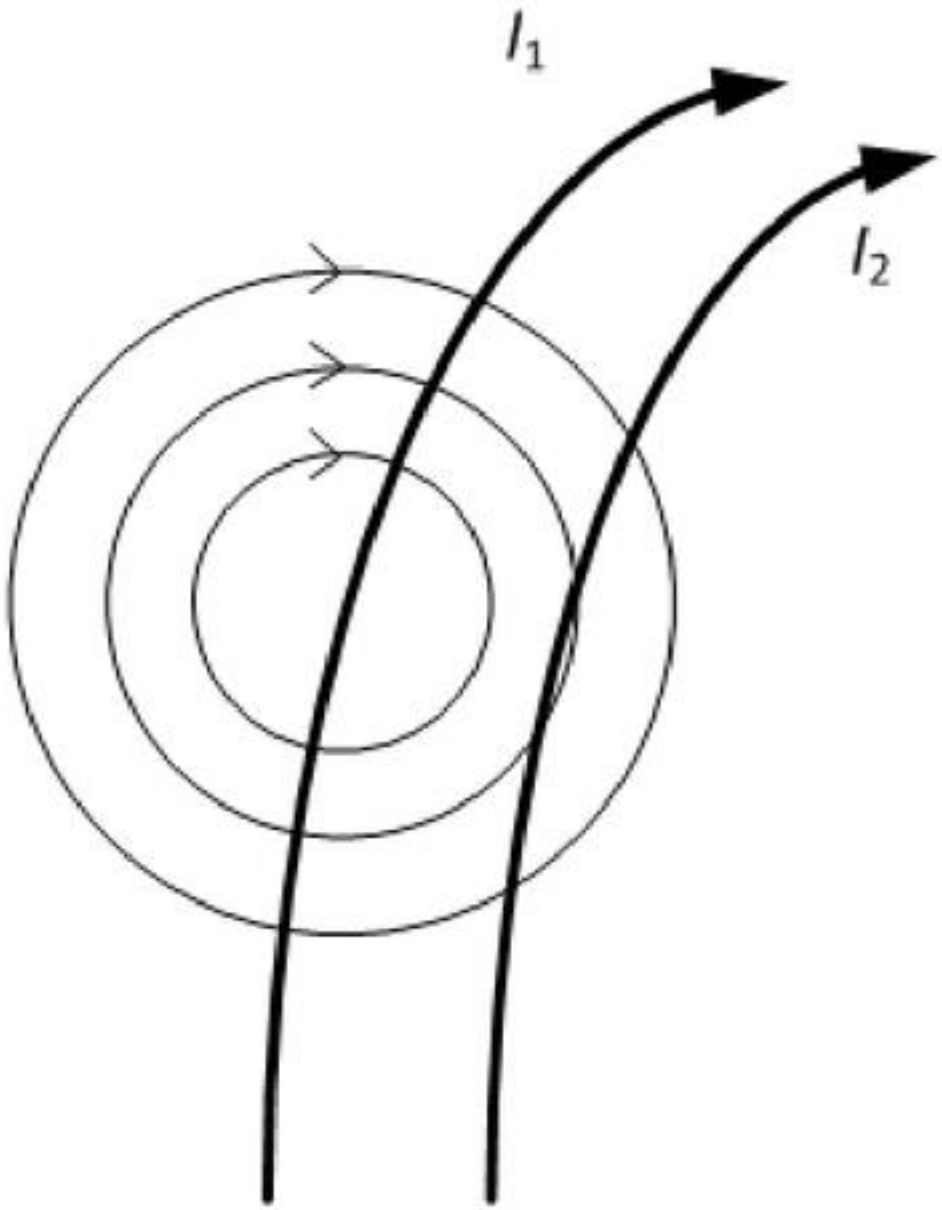
Konduktivno-radiativni prenos motenj

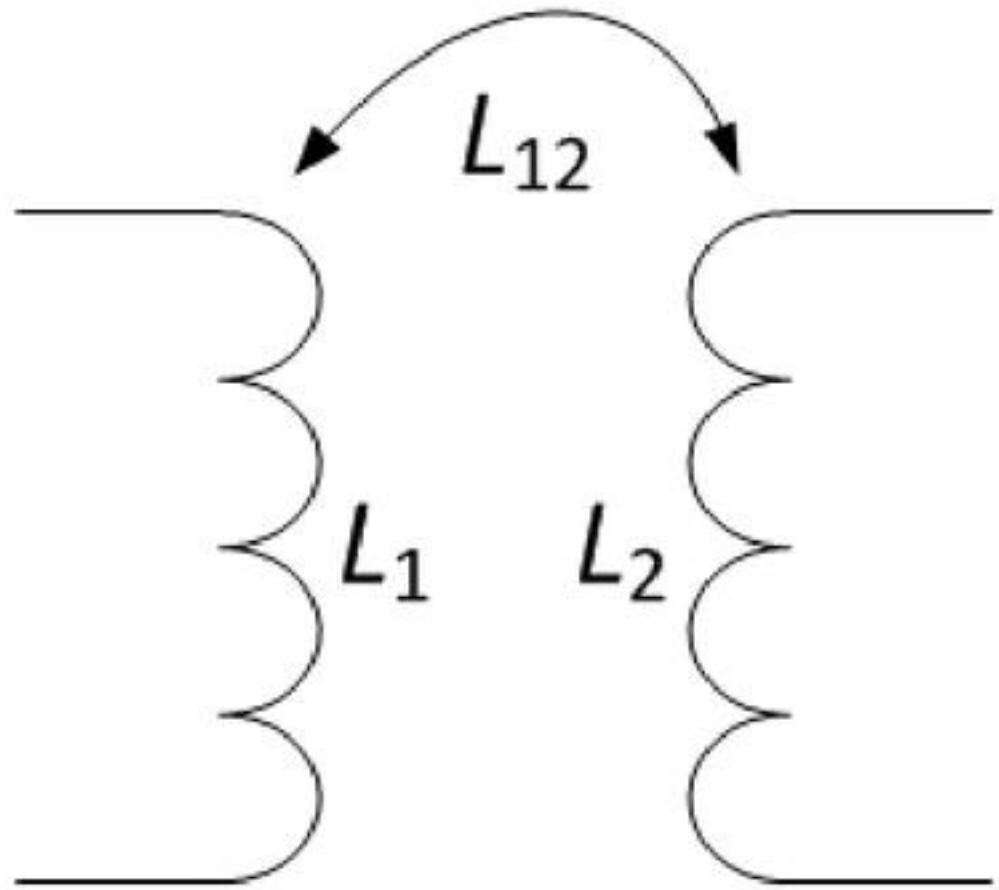


Kapacitivna povezava prek E polja

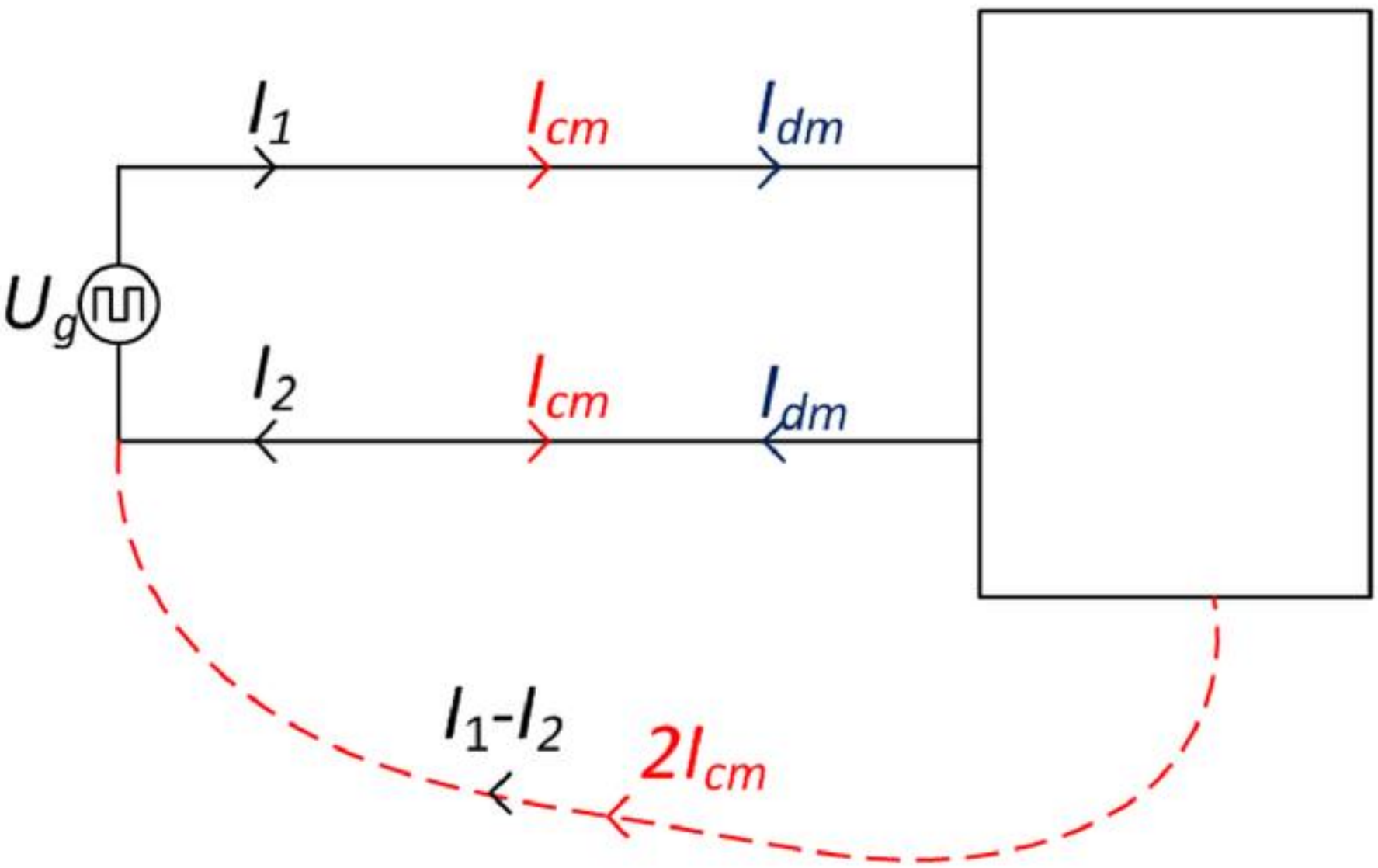


Induktivna povezava prek H polja





Diferencialni in sofazni signali



$$I_1 = I_{dm} + I_{cm}$$

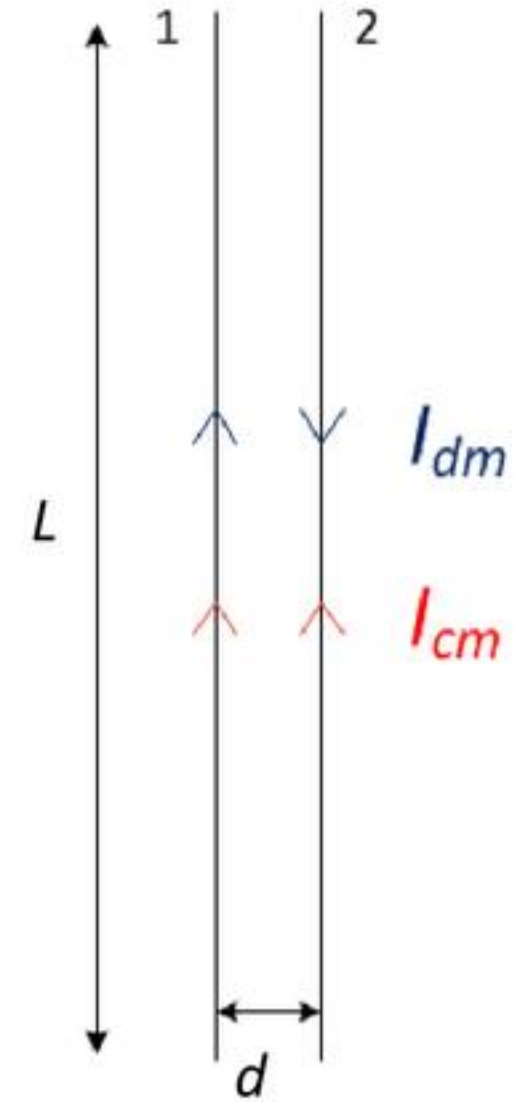
$$I_2 = I_{dm} - I_{cm}$$

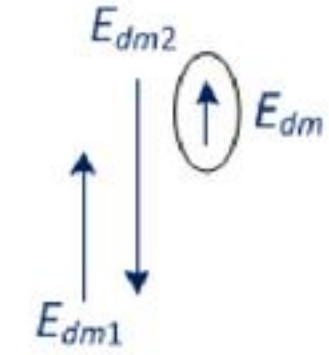
$$I_{dm} = \frac{I_1 + I_2}{2}$$

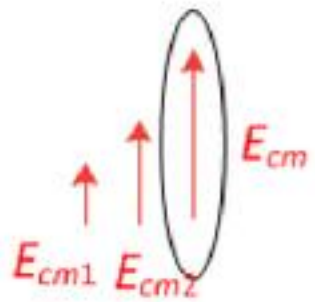
$$I_{cm} = \frac{I_1 - I_2}{2}$$

Diferencialne in sofazne motnje

$$E_{dm_{maks}}(f) = 2{,}632 \cdot 10^{-14} \frac{I_{dm}(f) f^2 L d}{R} \; V/m$$







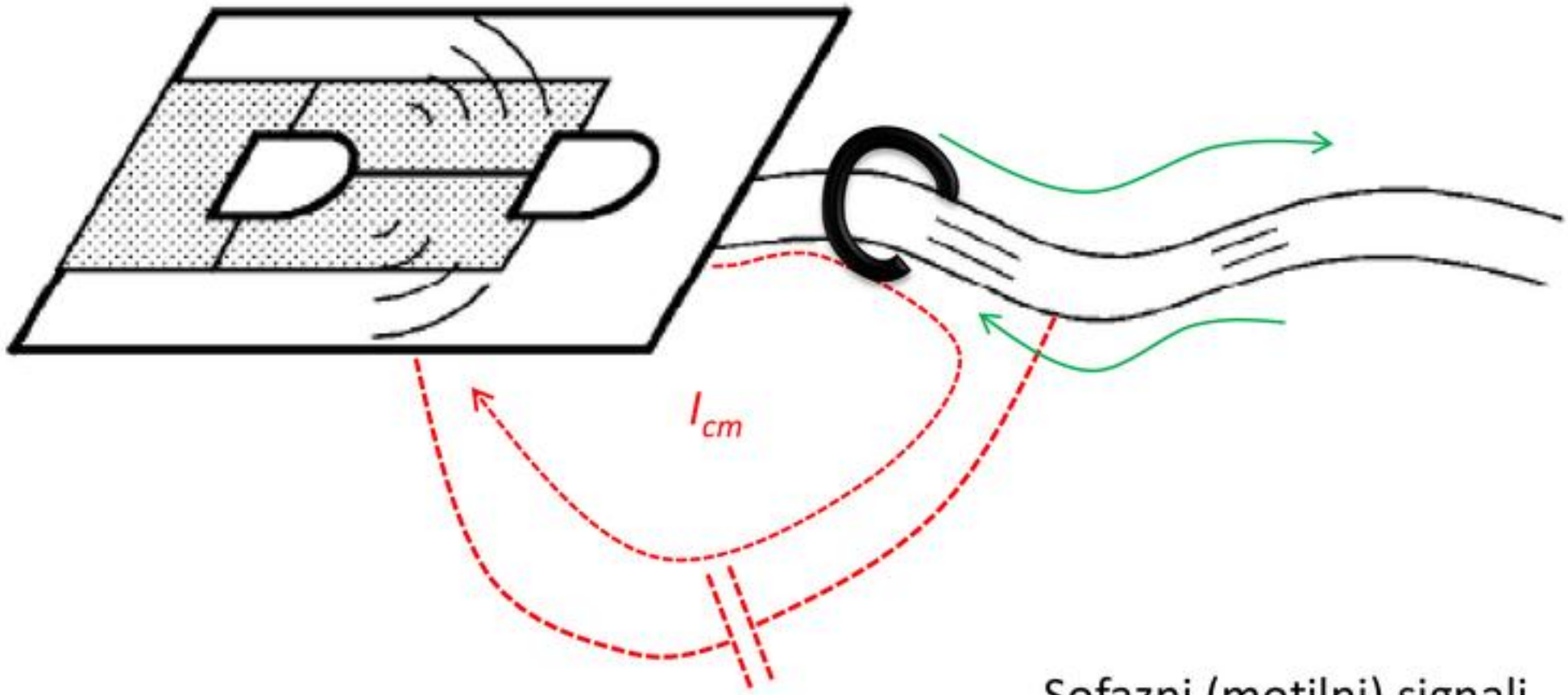
$$E_{cm_{maks}}(f) = 2{,}541 \cdot 10^{-6} \frac{I_{cm}(f) f L}{R} \; V/m$$

Primer

- Signali na PCB
  - › Majhne tokovne zanke (A)
  - › Protifazni zančni tokovi (I)
  - › $Edm = 265 \cdot 10^{-16} \frac{I_{dm} A f^2}{R}$
- $I = 1\,mA, f = 100\,MHz, A = 1\,cm^2$
- $E = 26 \frac{\mu V}{m} @ 1\,m$

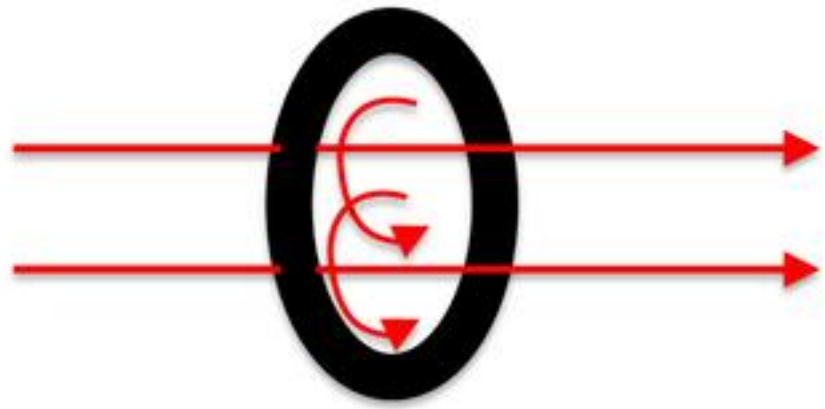
- Signali na povezovalnem kablu
  - › Velike dipolne antene (dolžine L)
  - › Sofazni tokovi (I)
  - › $Ecm = 4 \cdot 10^{-7} \frac{I_{cm} f L}{R}$
- $I = 200\,pA, f = 100MHz, L = 1m$
- $E = 26 \frac{\mu V}{m} @ 1\,m$

Feritni obroček

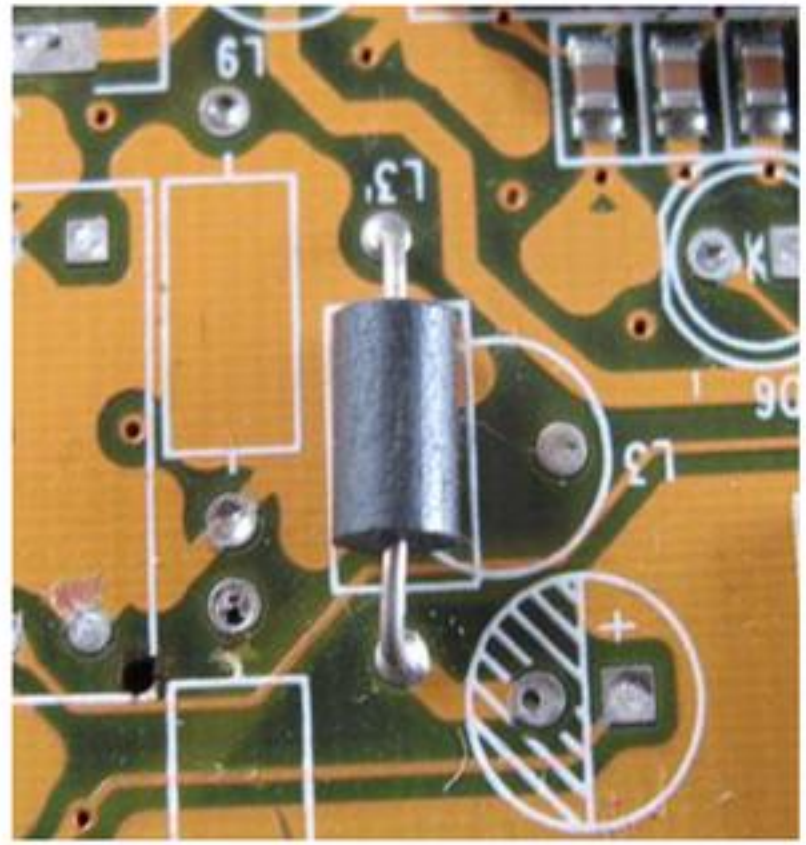


Diferencialni (koristni) signali

Sofazni (motilni) signali

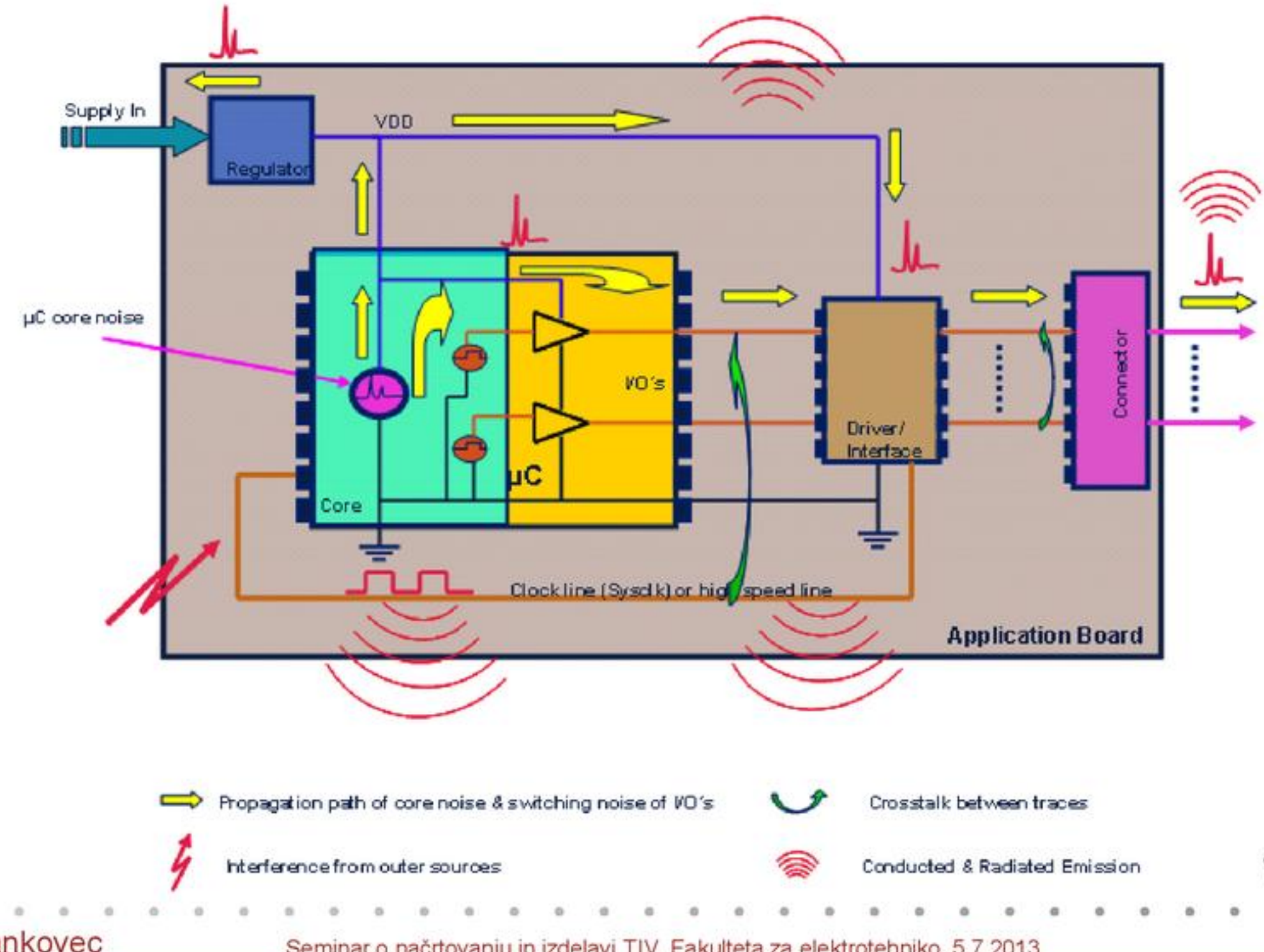


Različni feritni obročki



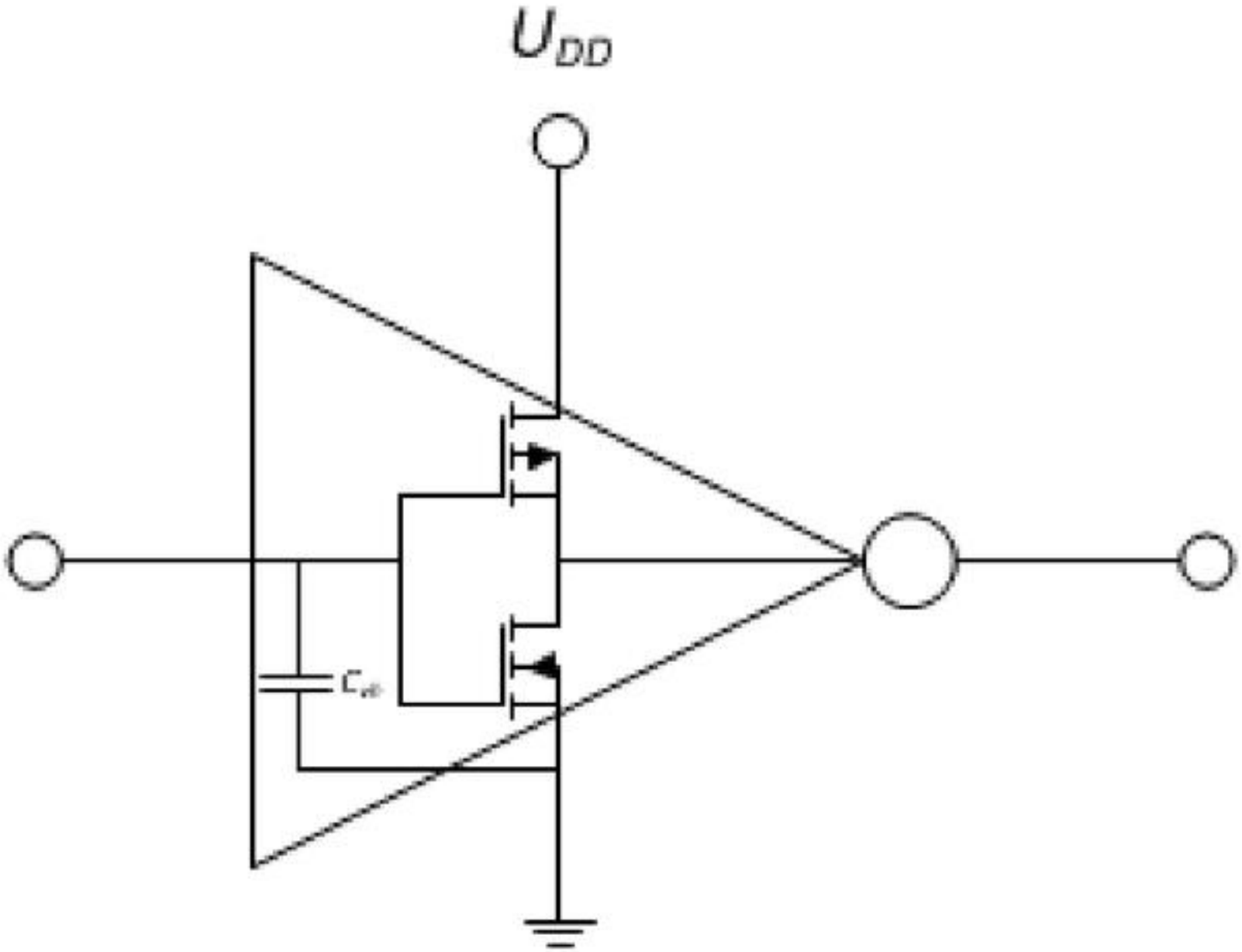
Kitajska tablica

Viri EMI v digitalnem elektronskem vezju

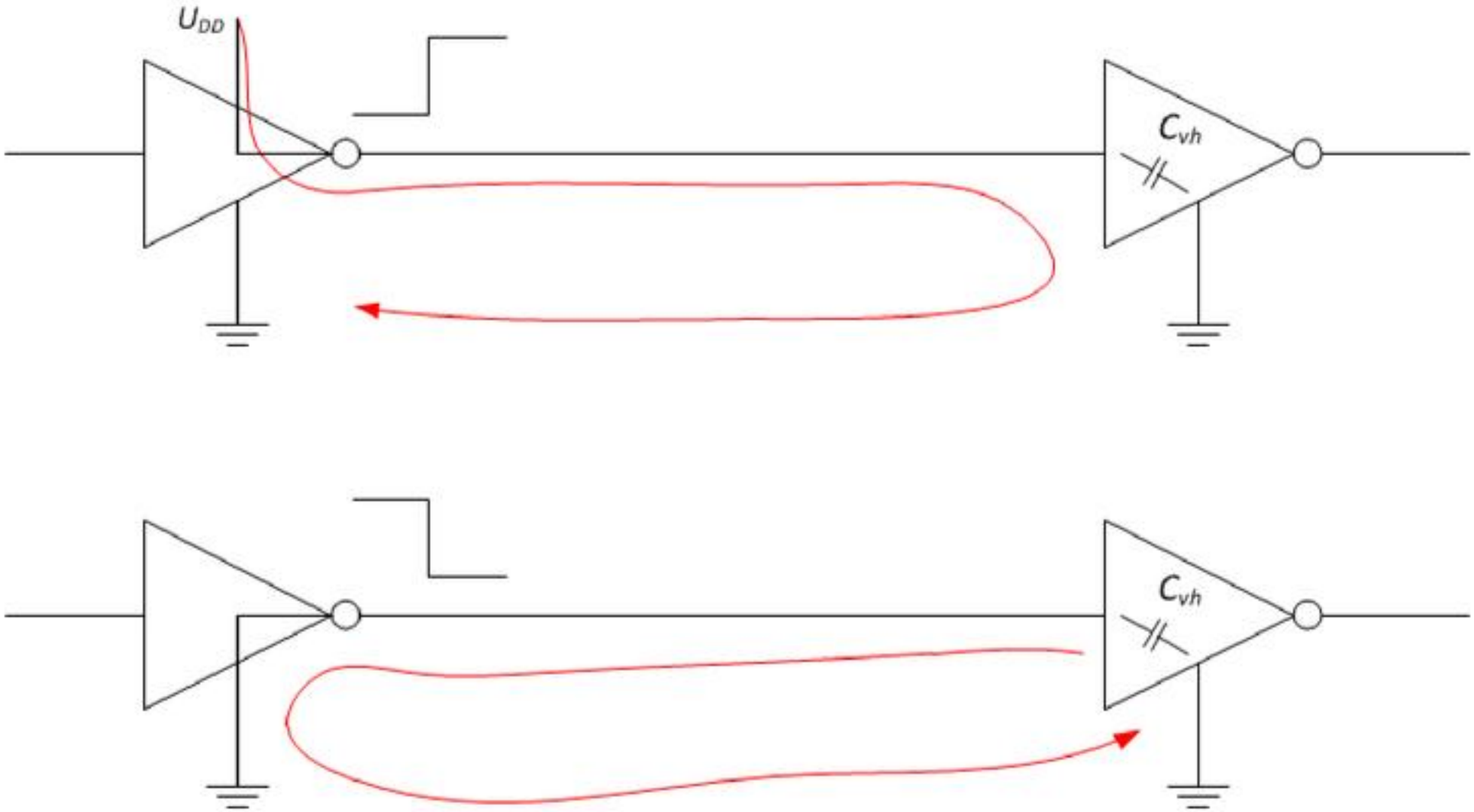


Vir: Infineon

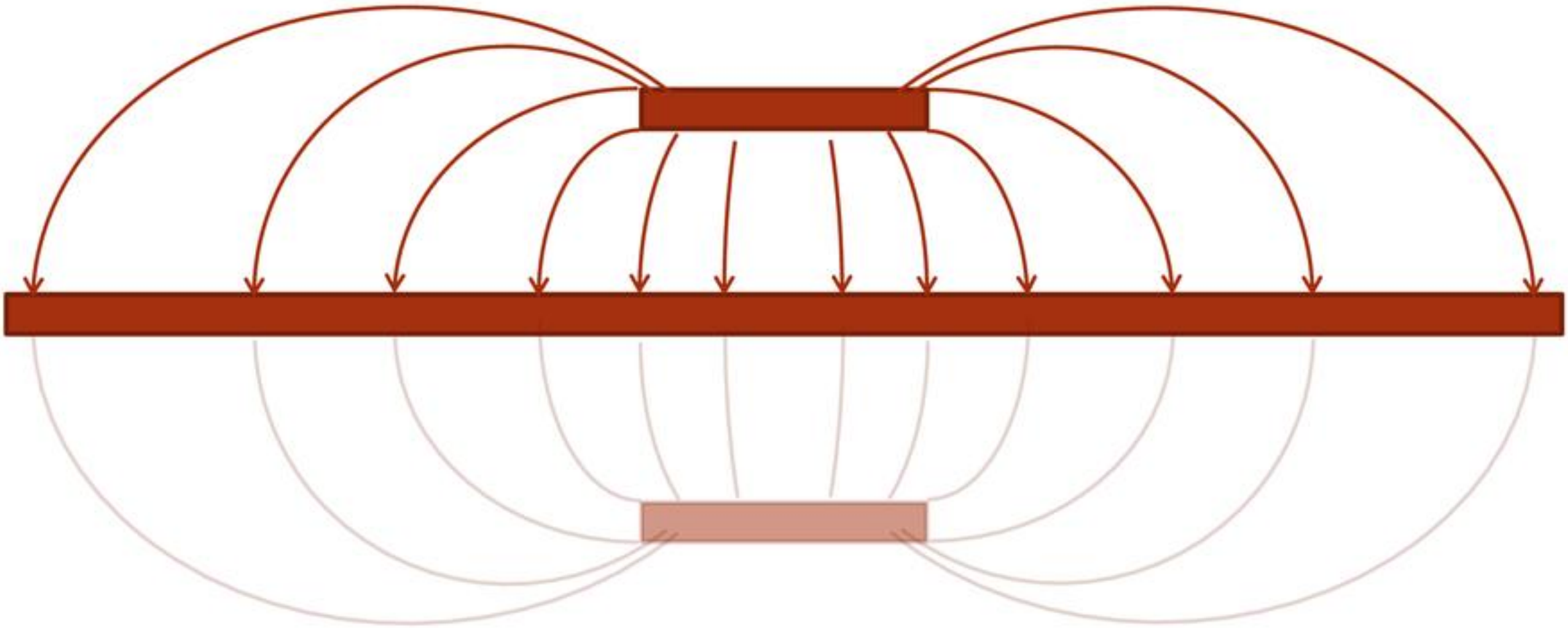
Tipično nadomestno vezje logičnih vrat



Kirchhofov tokovni zakon velja vedno

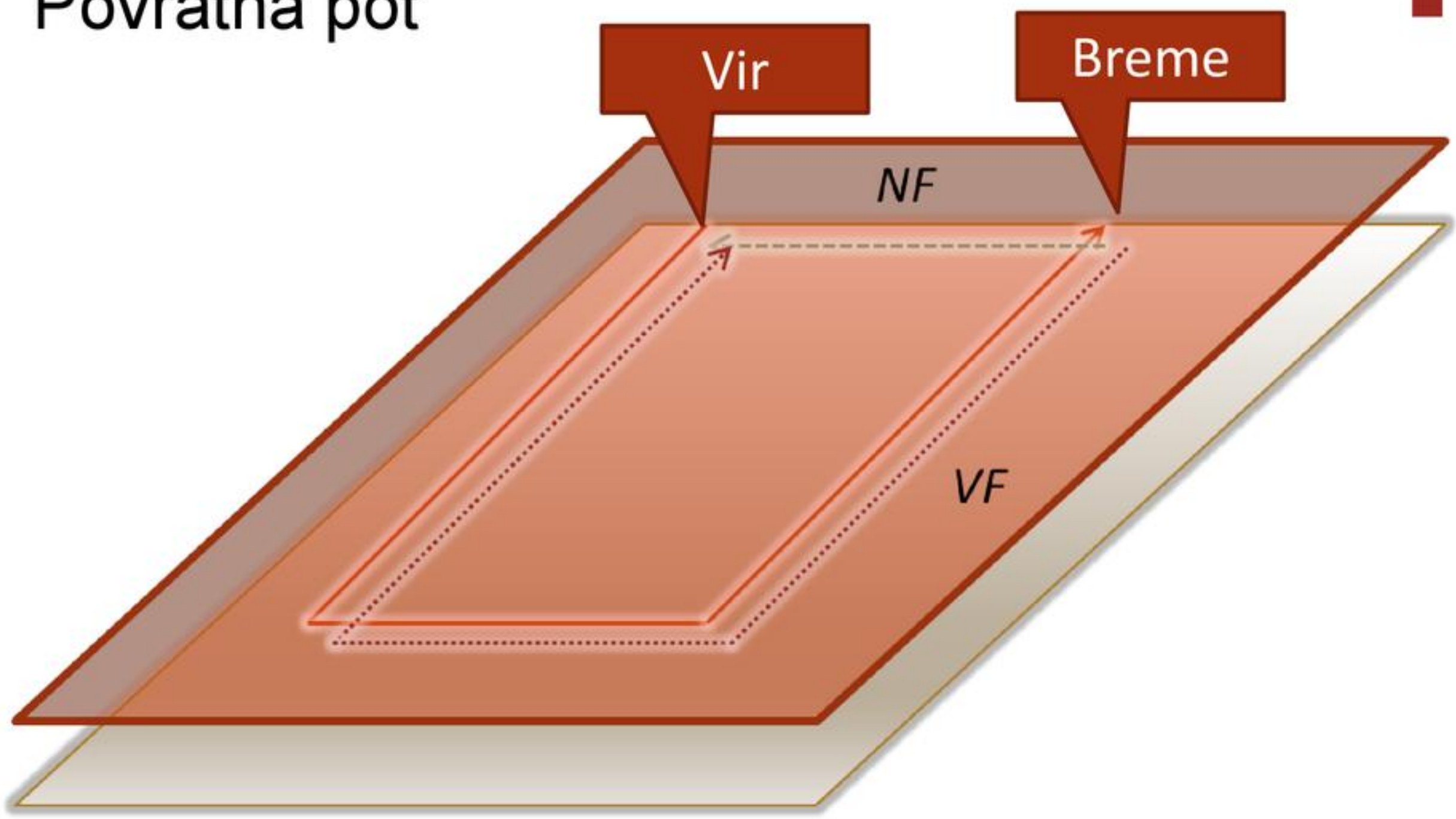


Zrcalna ravnina

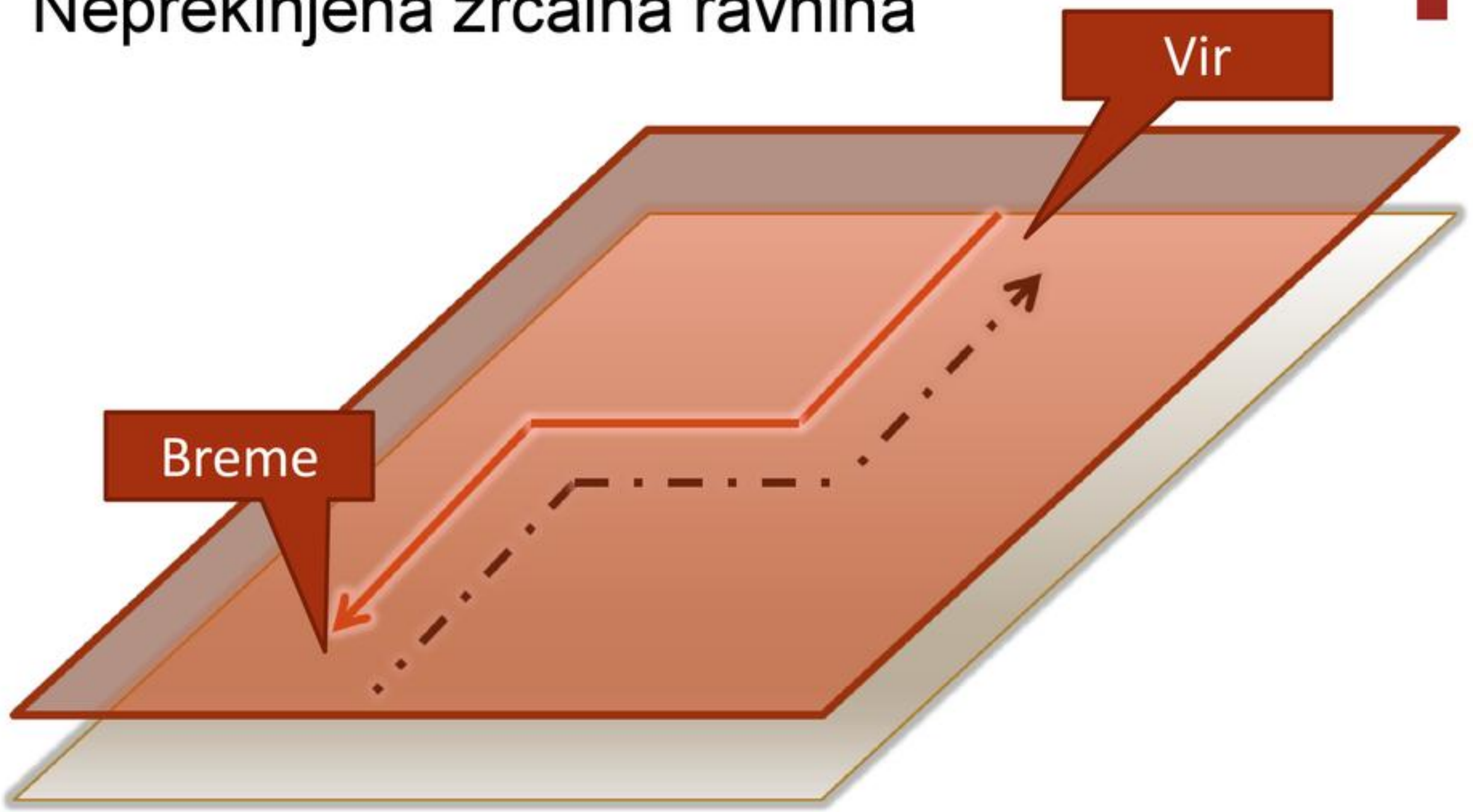


navidezna zrcalna slika

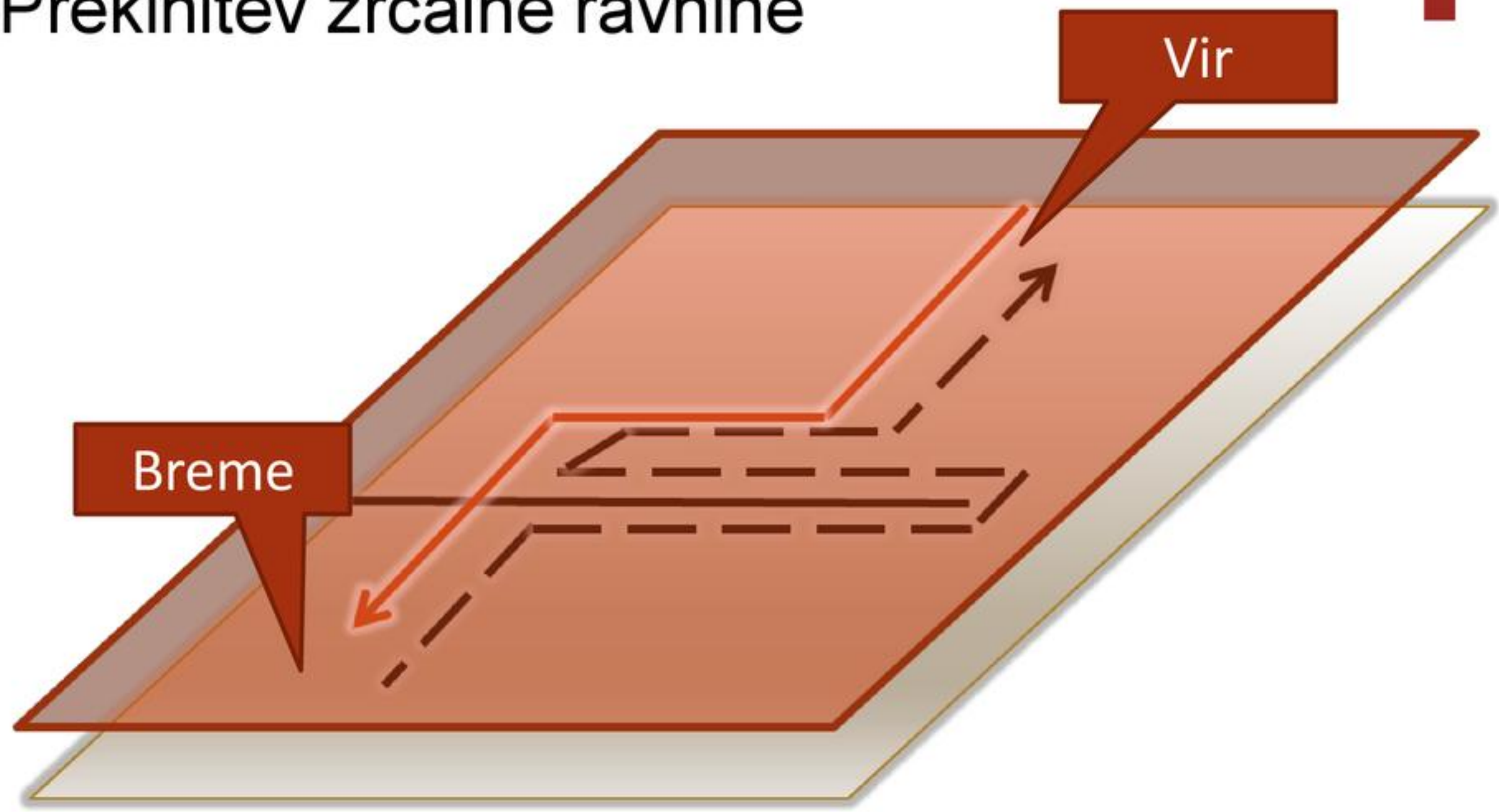
Povratna pot



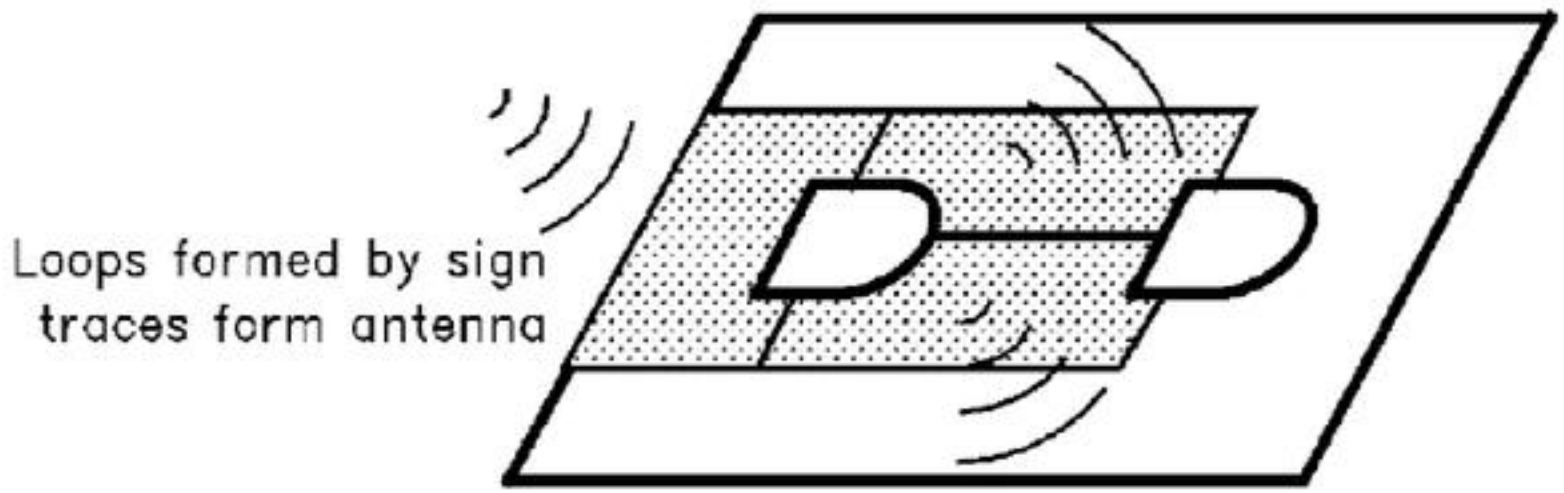
Neprekinjena zrcalna ravnina

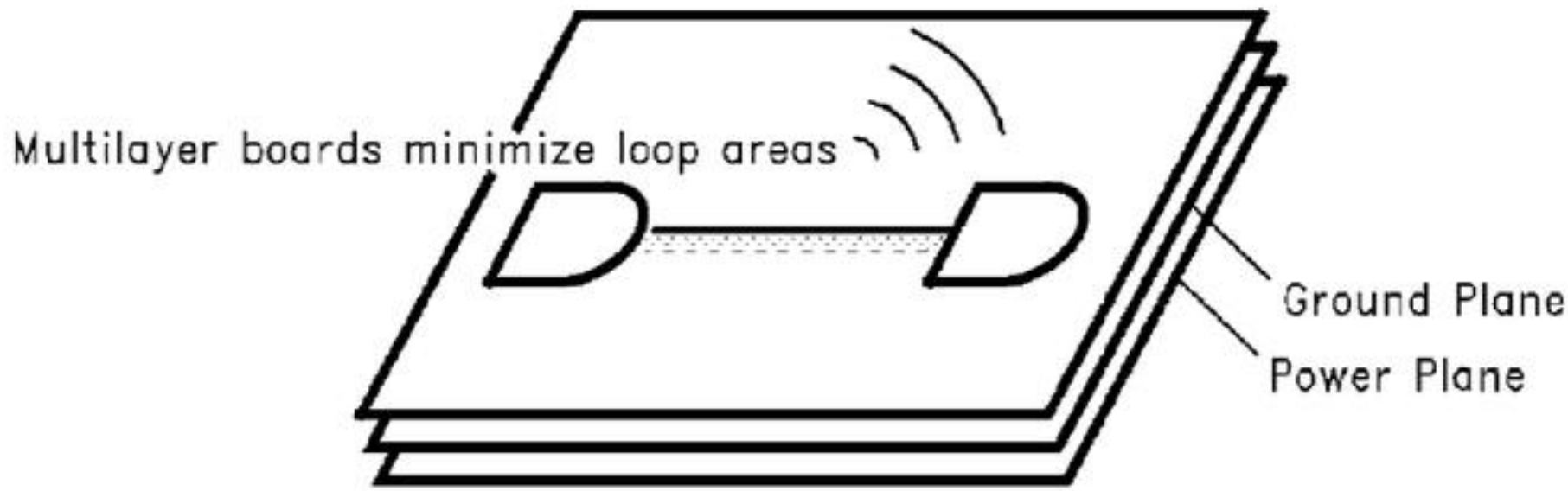


Prekinitev zrcalne ravnine

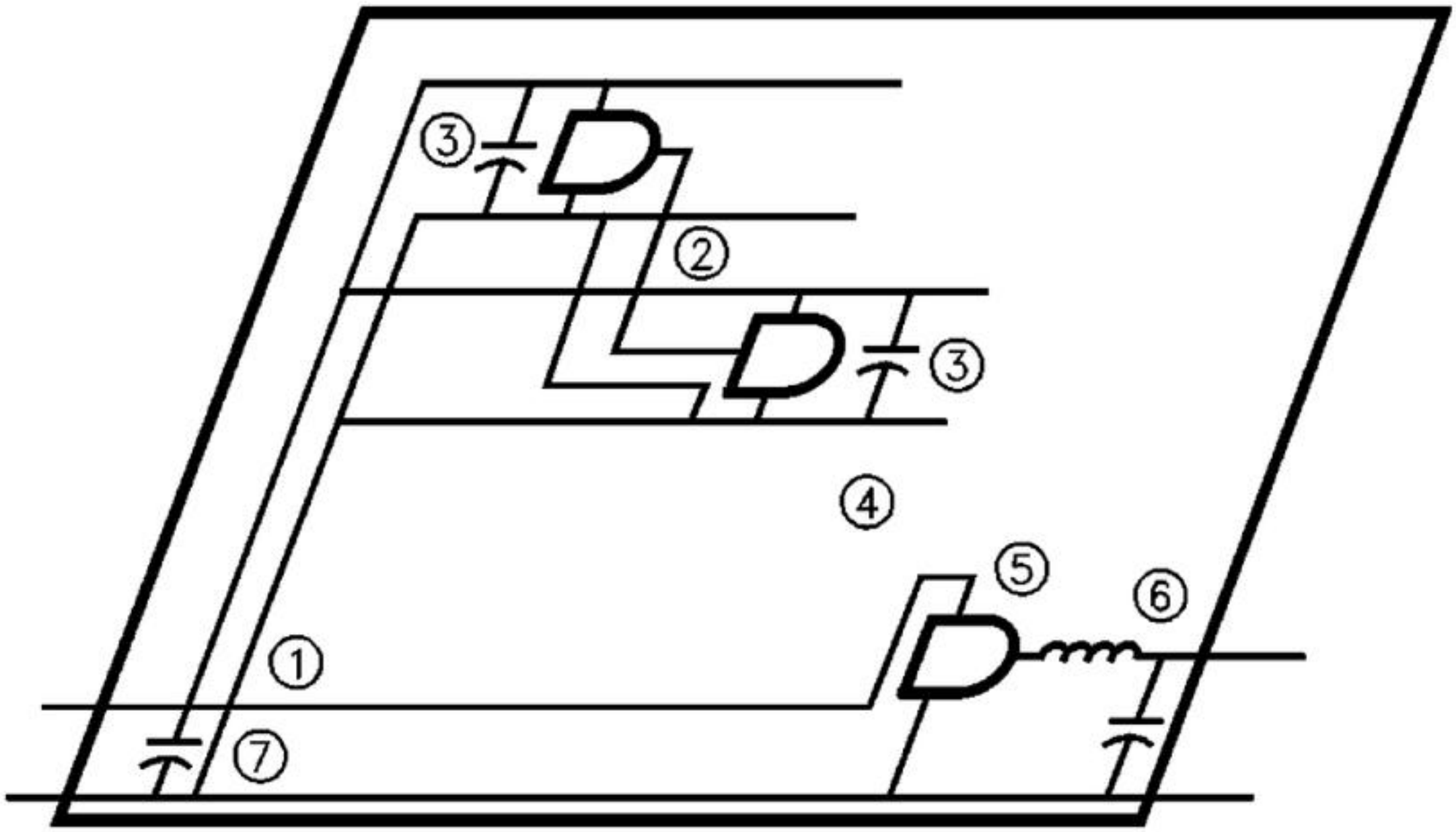


Izbira optimalne strukture plasti PCB



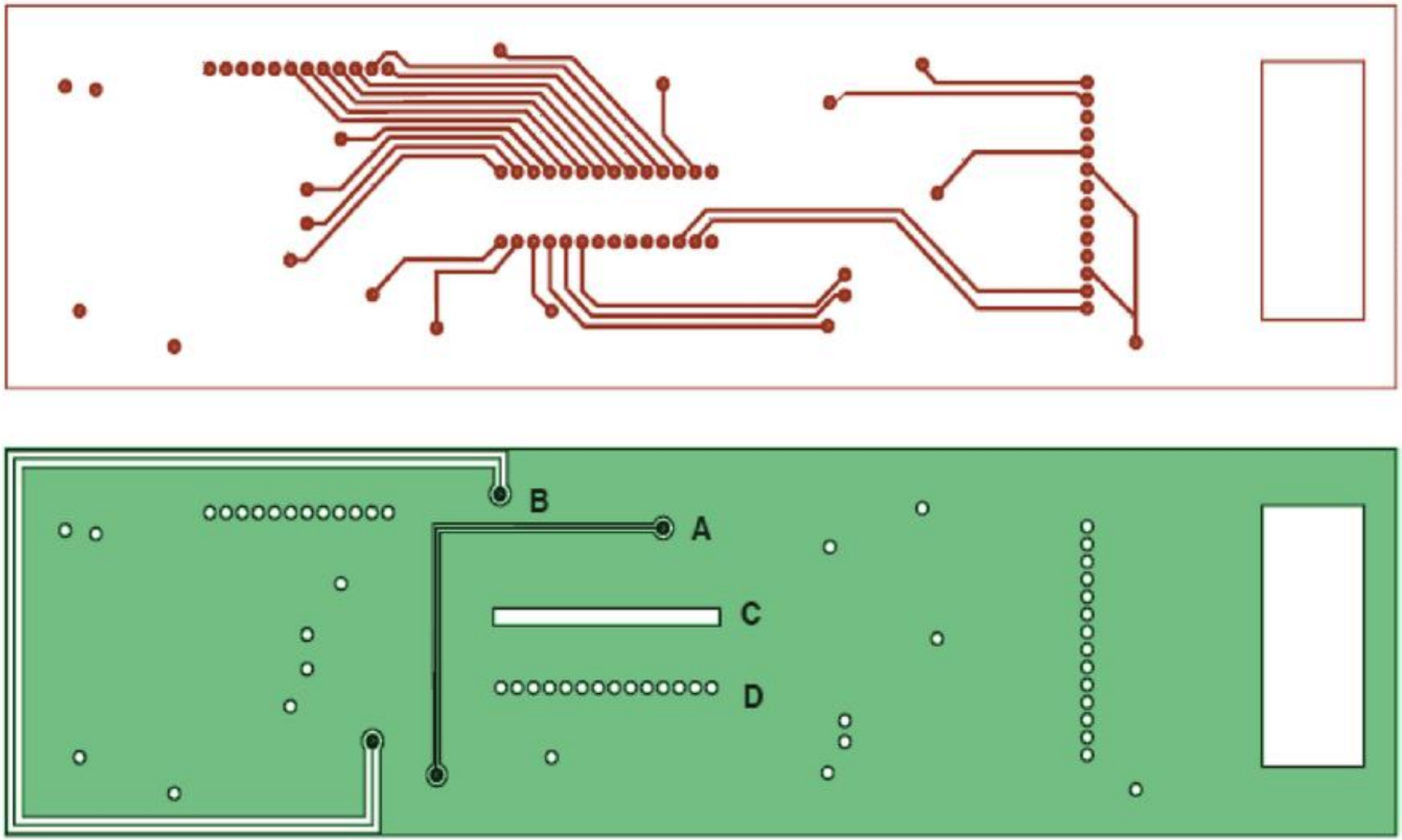


Ukrepi na dvoplastnih vezjih

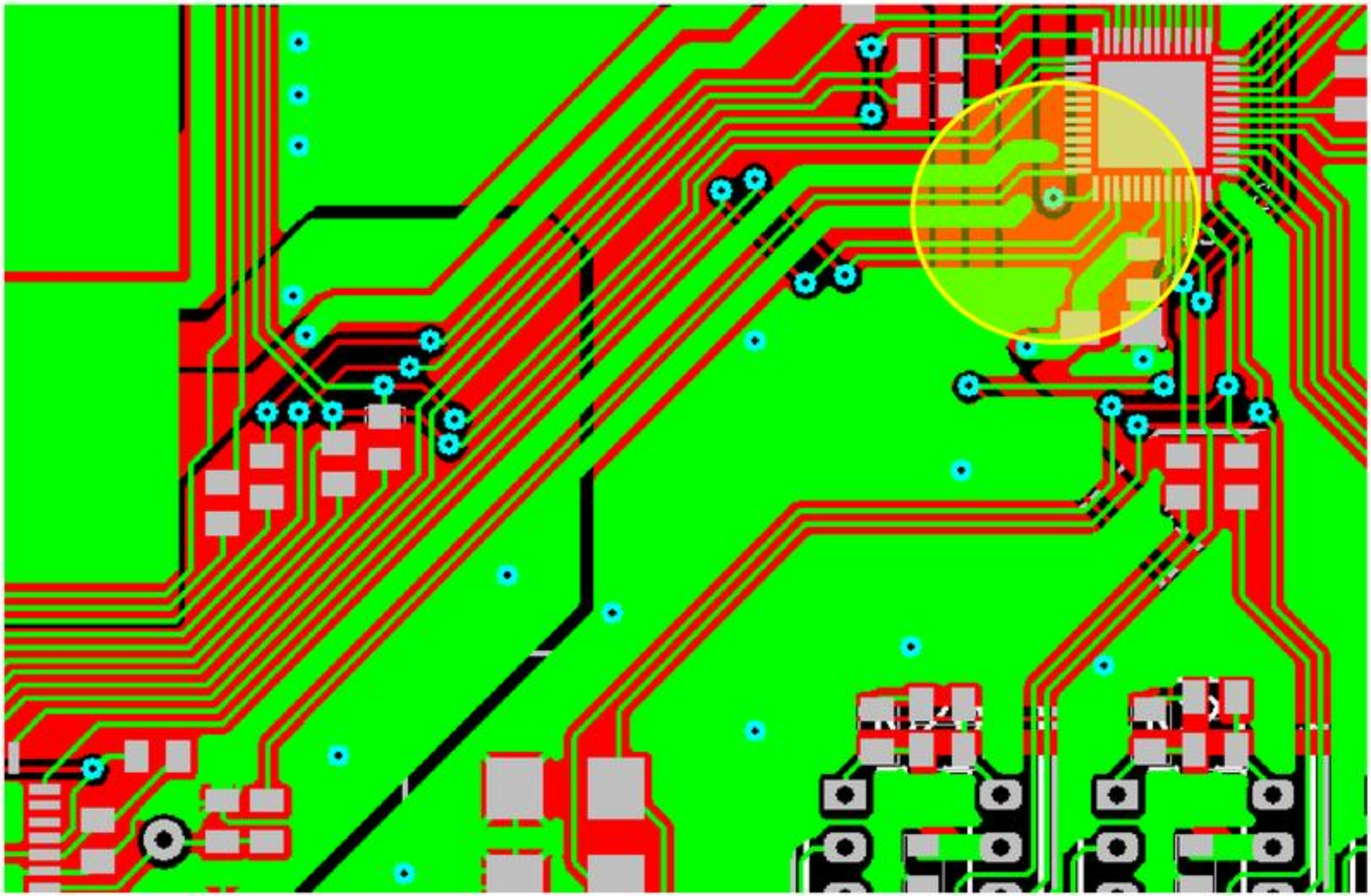


Vir: Intel application note 711

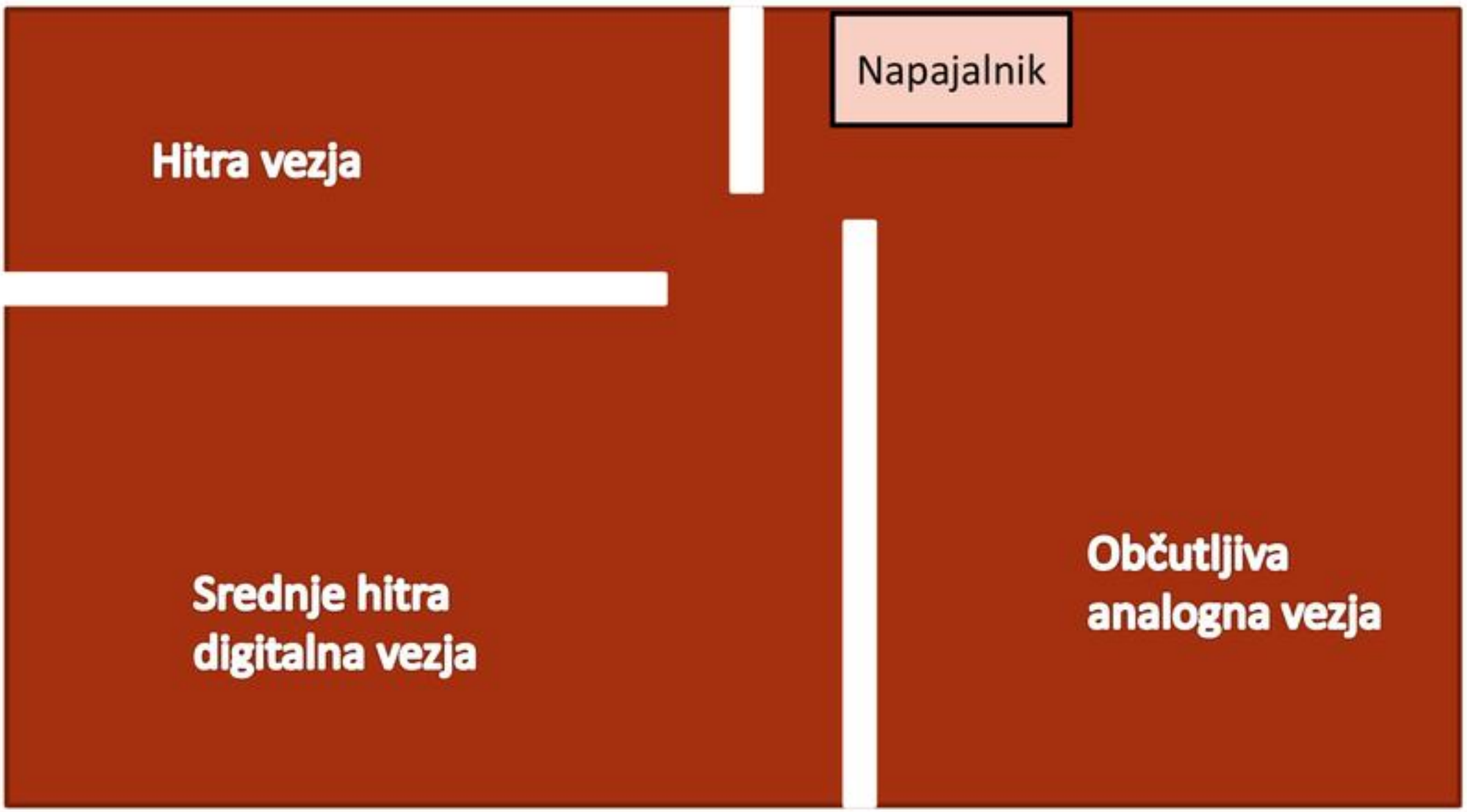
Prekinitev zrcalne ravnine



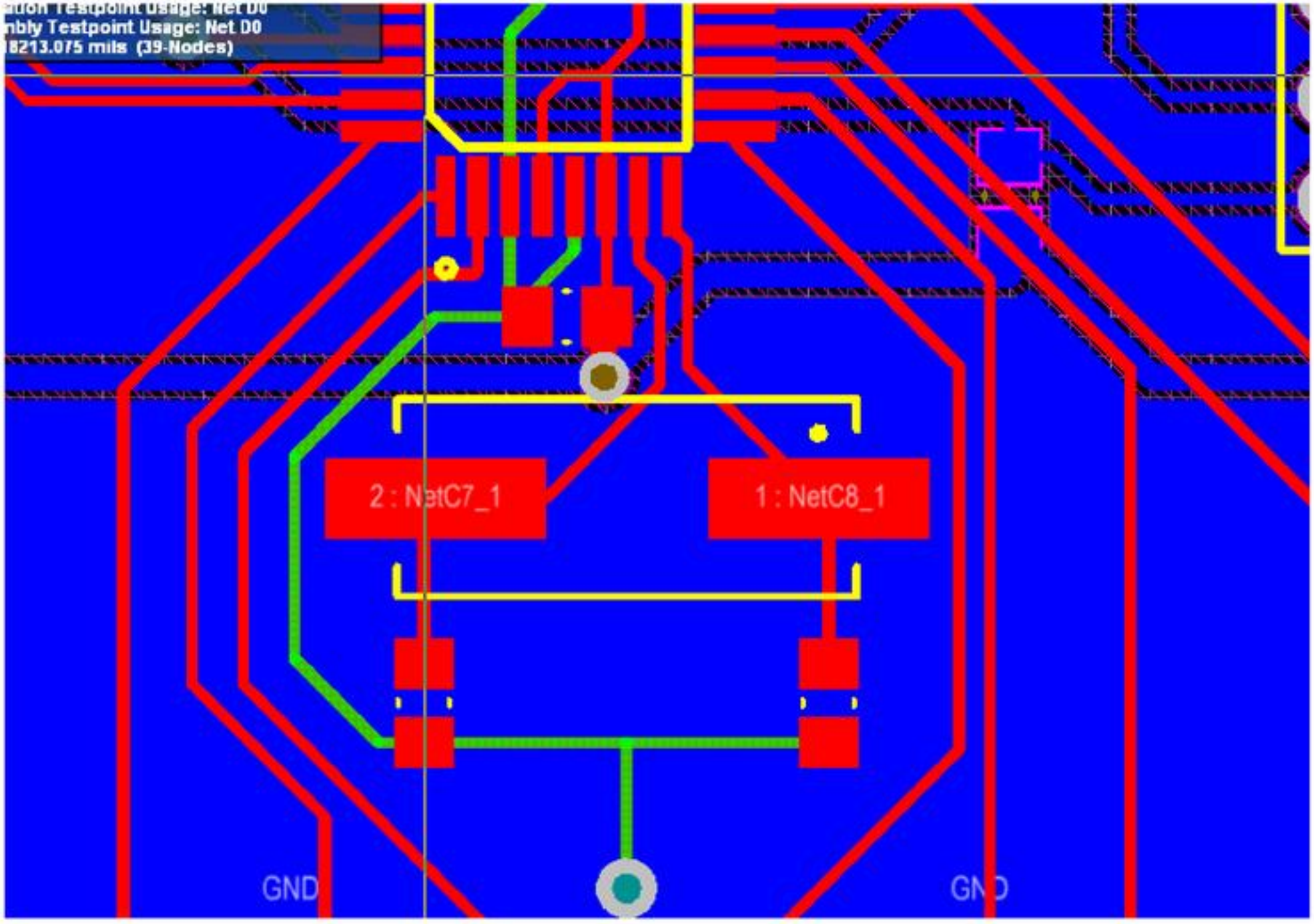
Prekinitev zrcalne ravnine



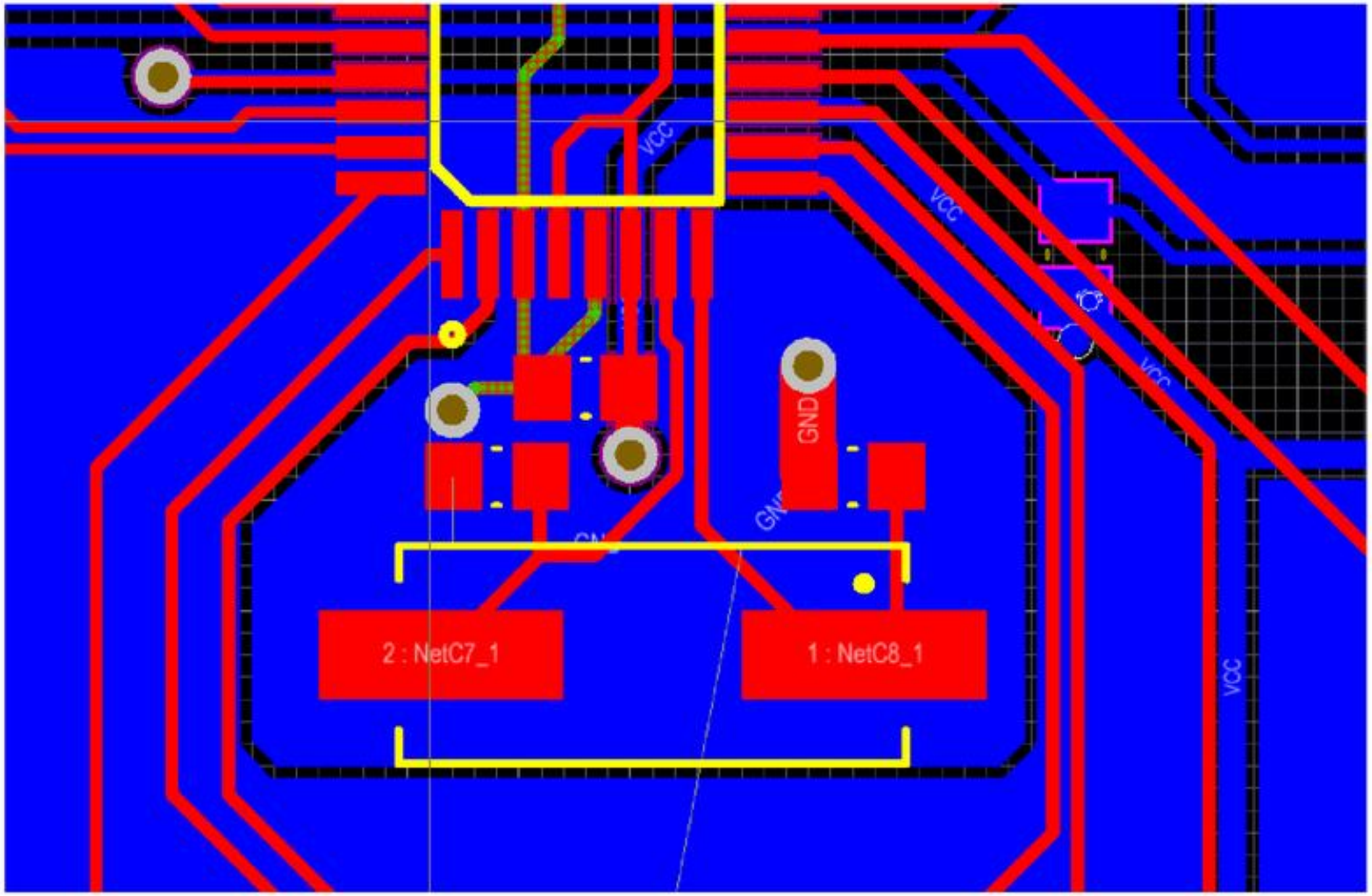
Segmentacija zrcalne ravnine



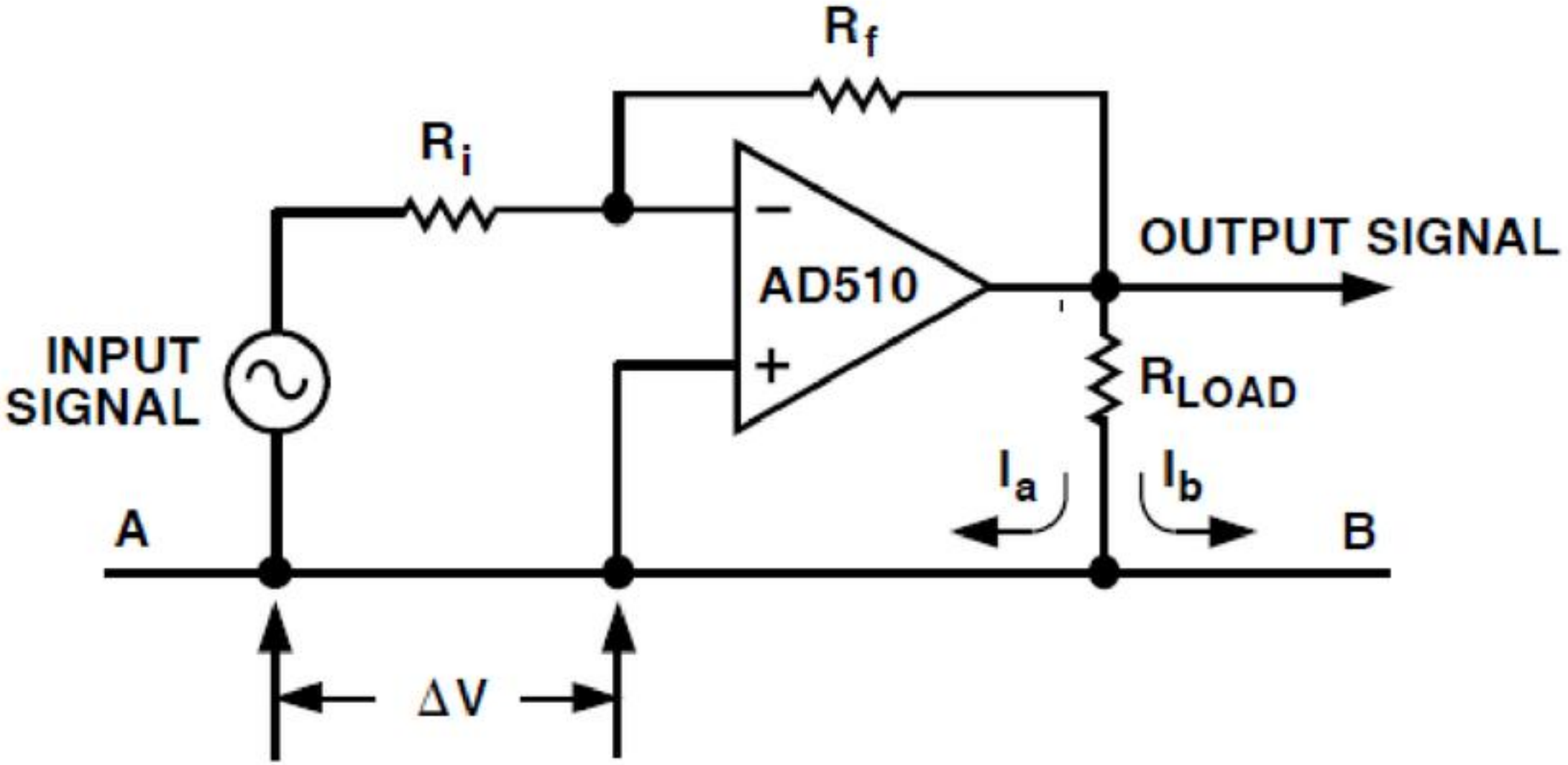
Primer napačnega priklopa kristala



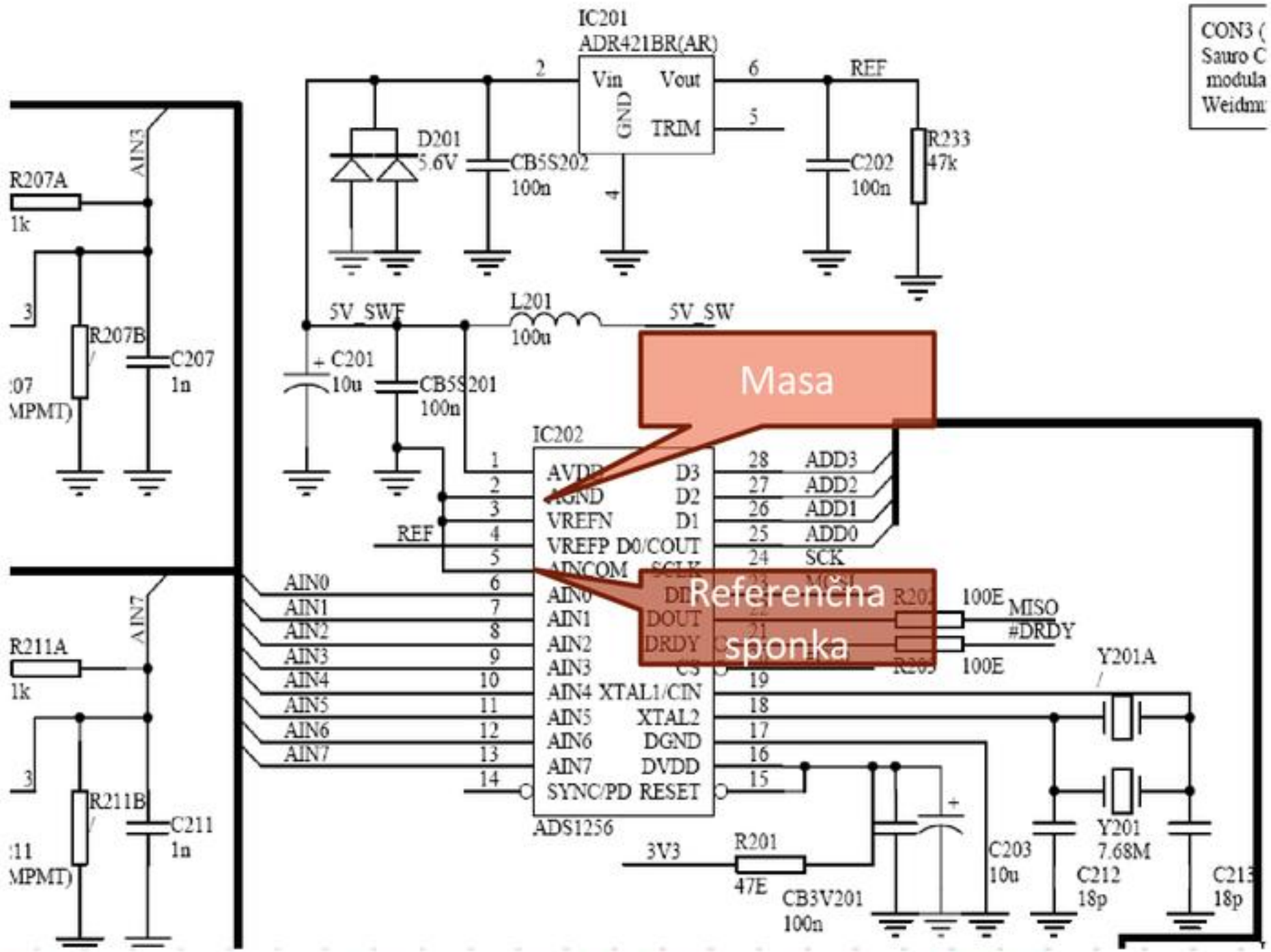
Popravek



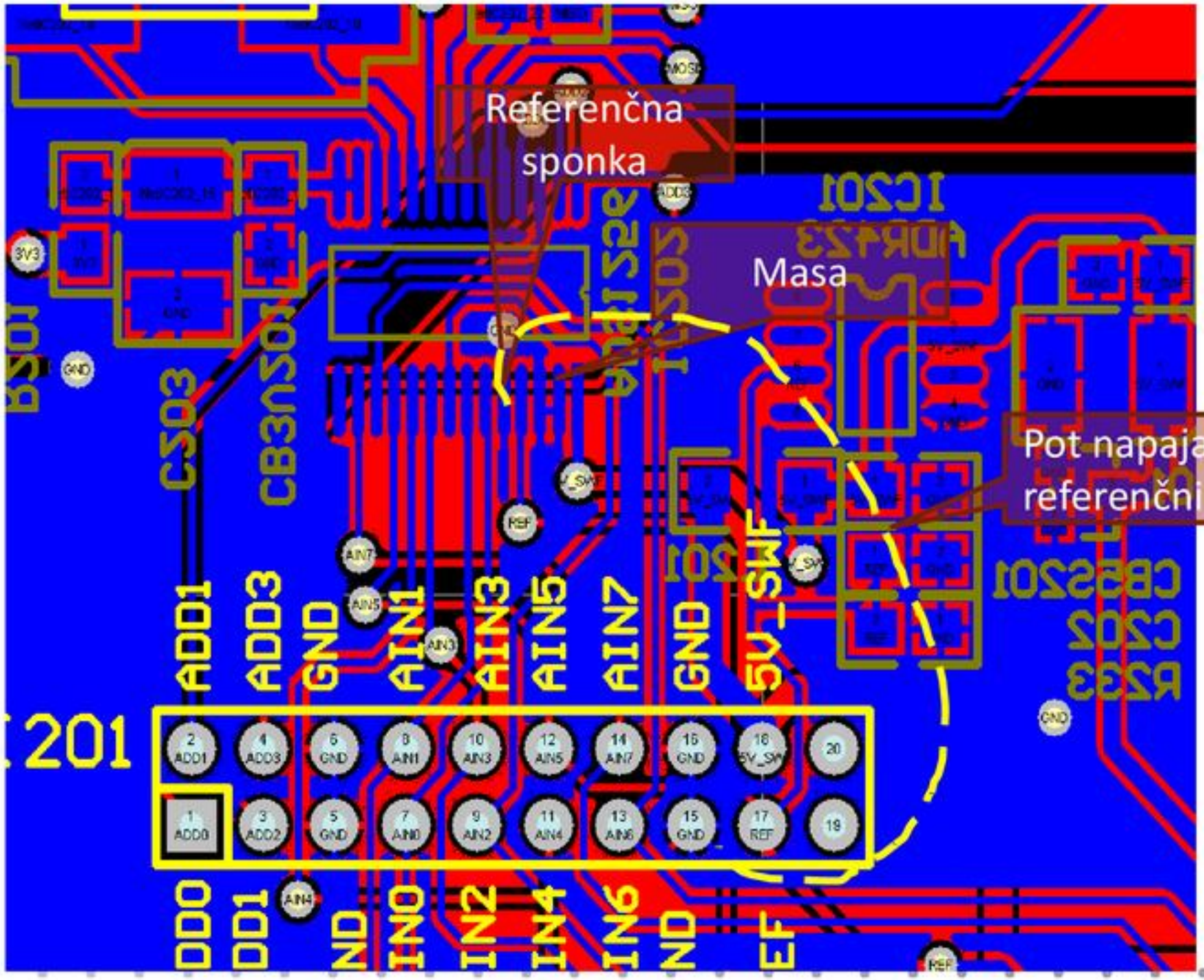
Problem skupne mase



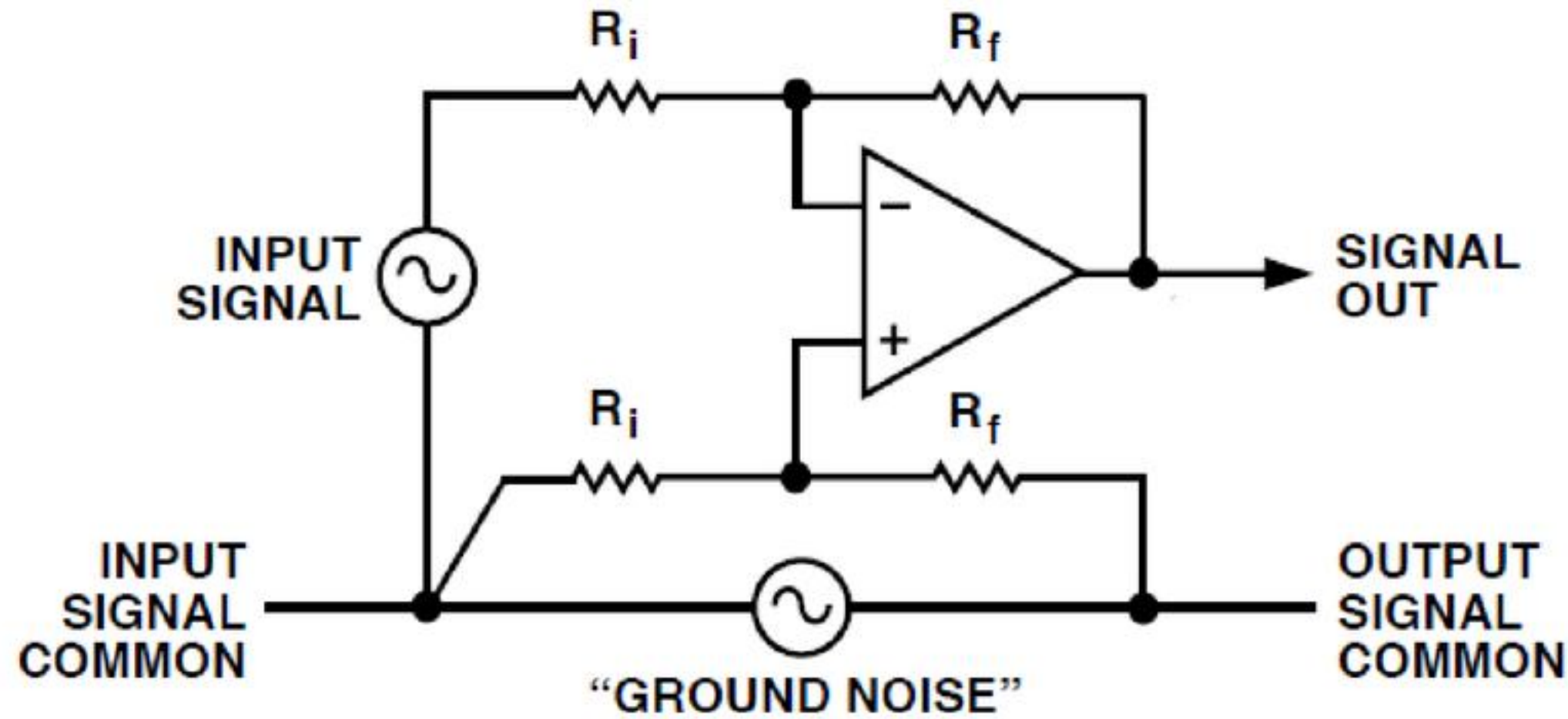
Problem konduktivnih motenj preko mase



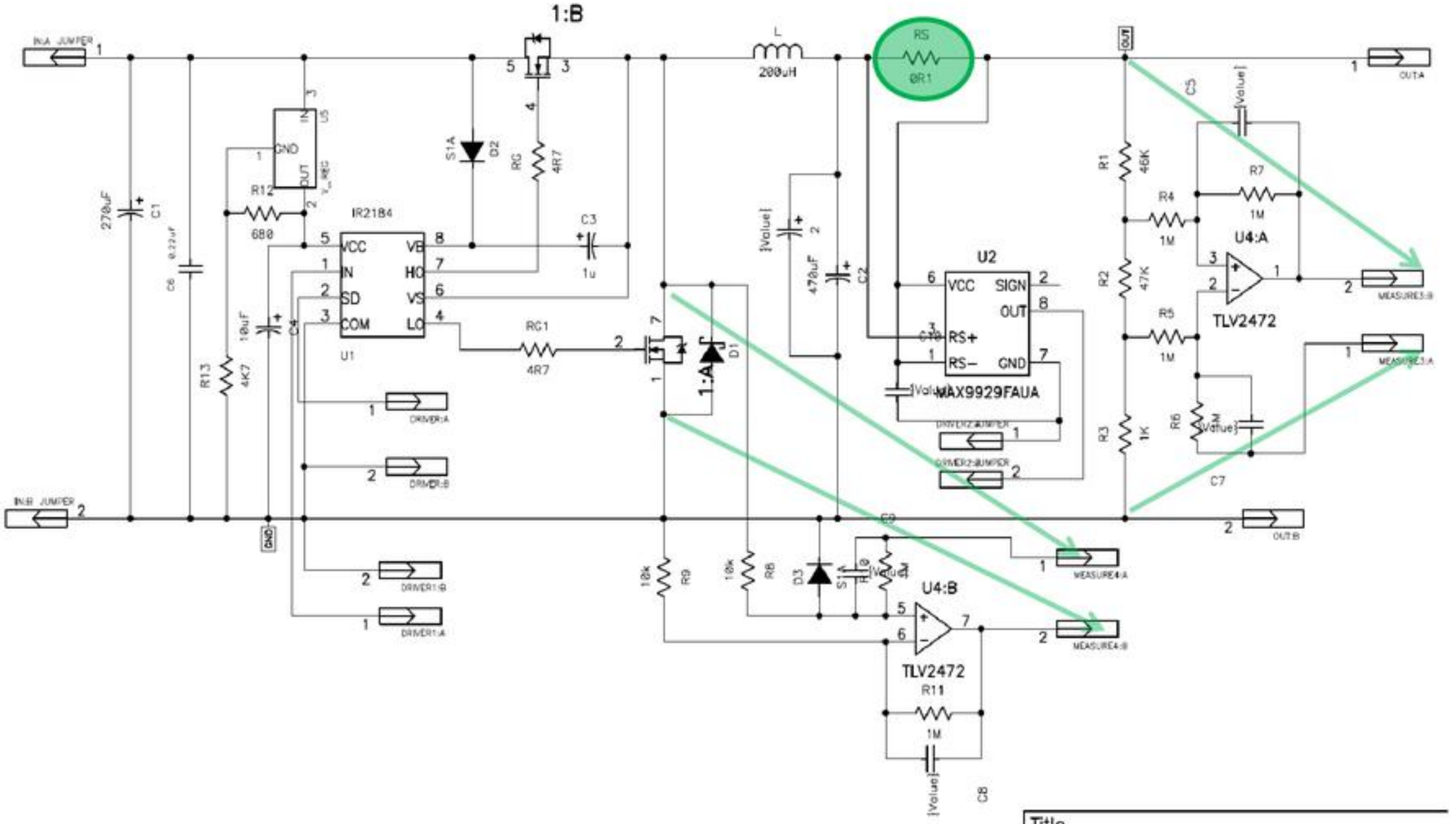
Problem konduktivnih motenj preko mase



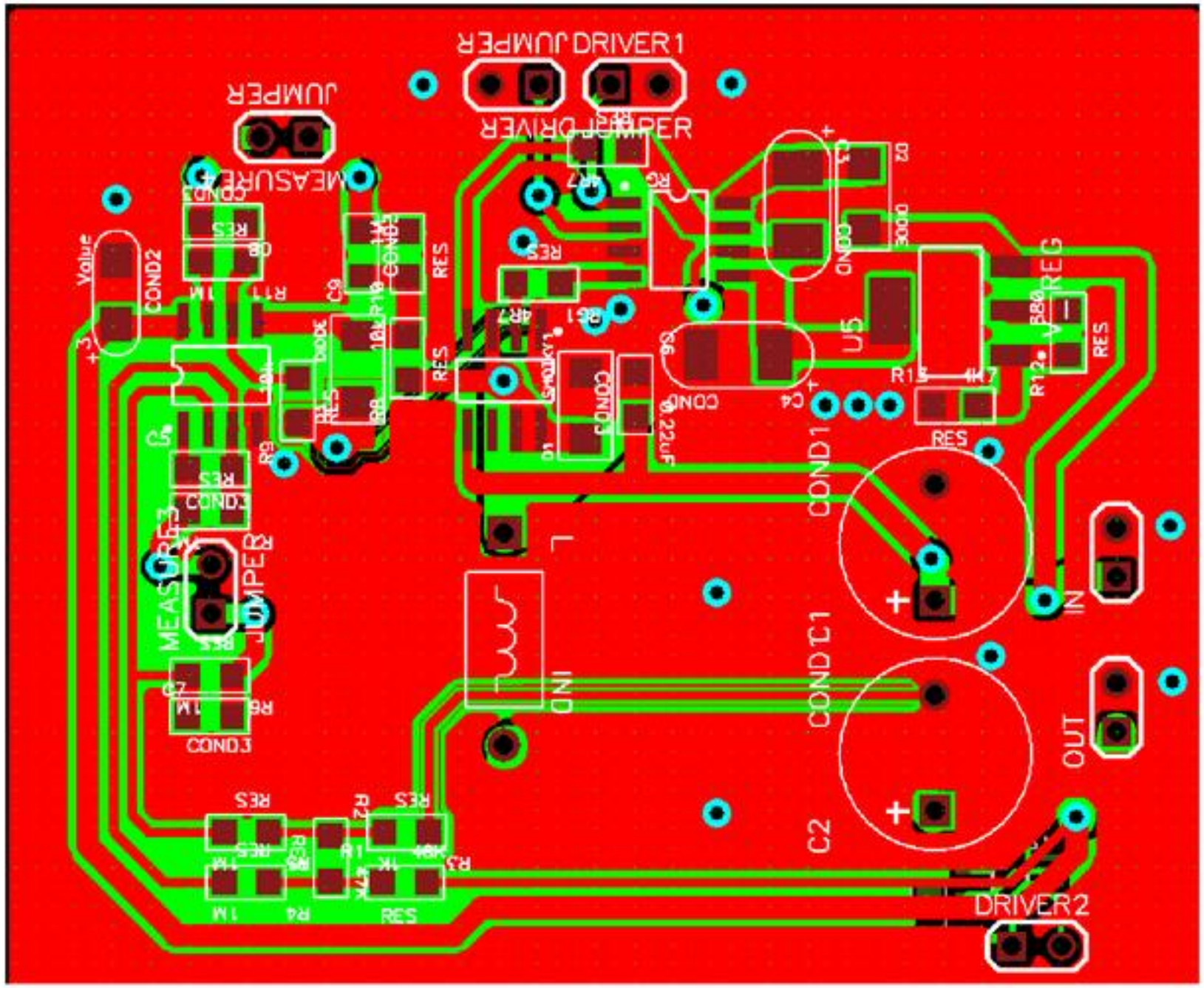
Diferencialni ojačevalnik



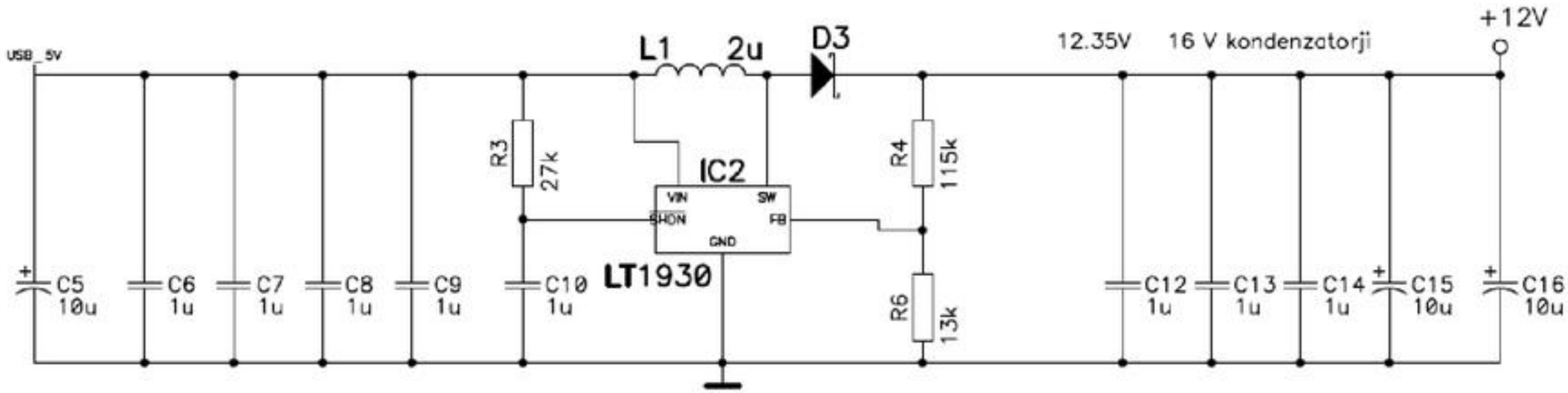
Diferencialni zajem signala



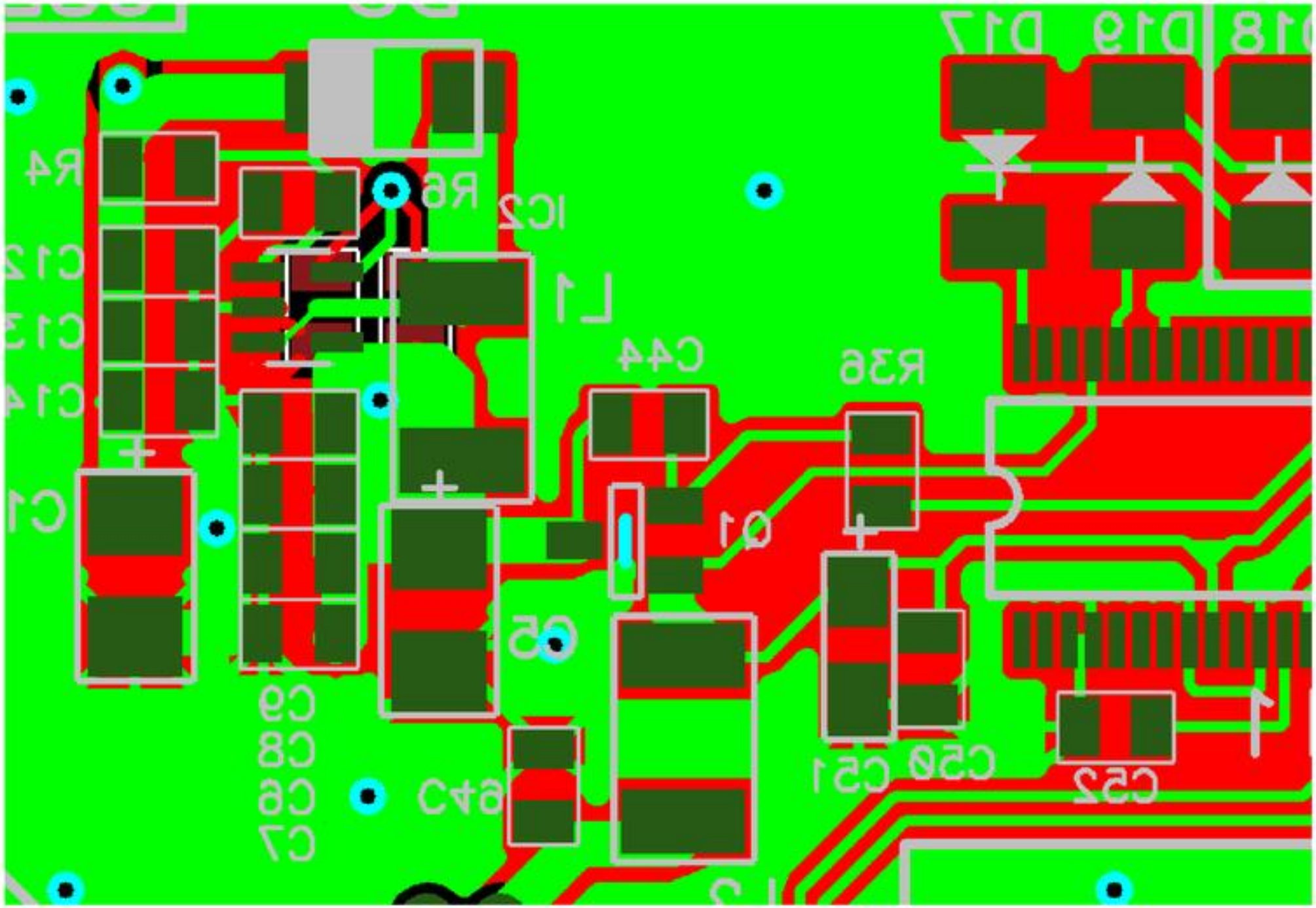
Diferencialni zajem signala



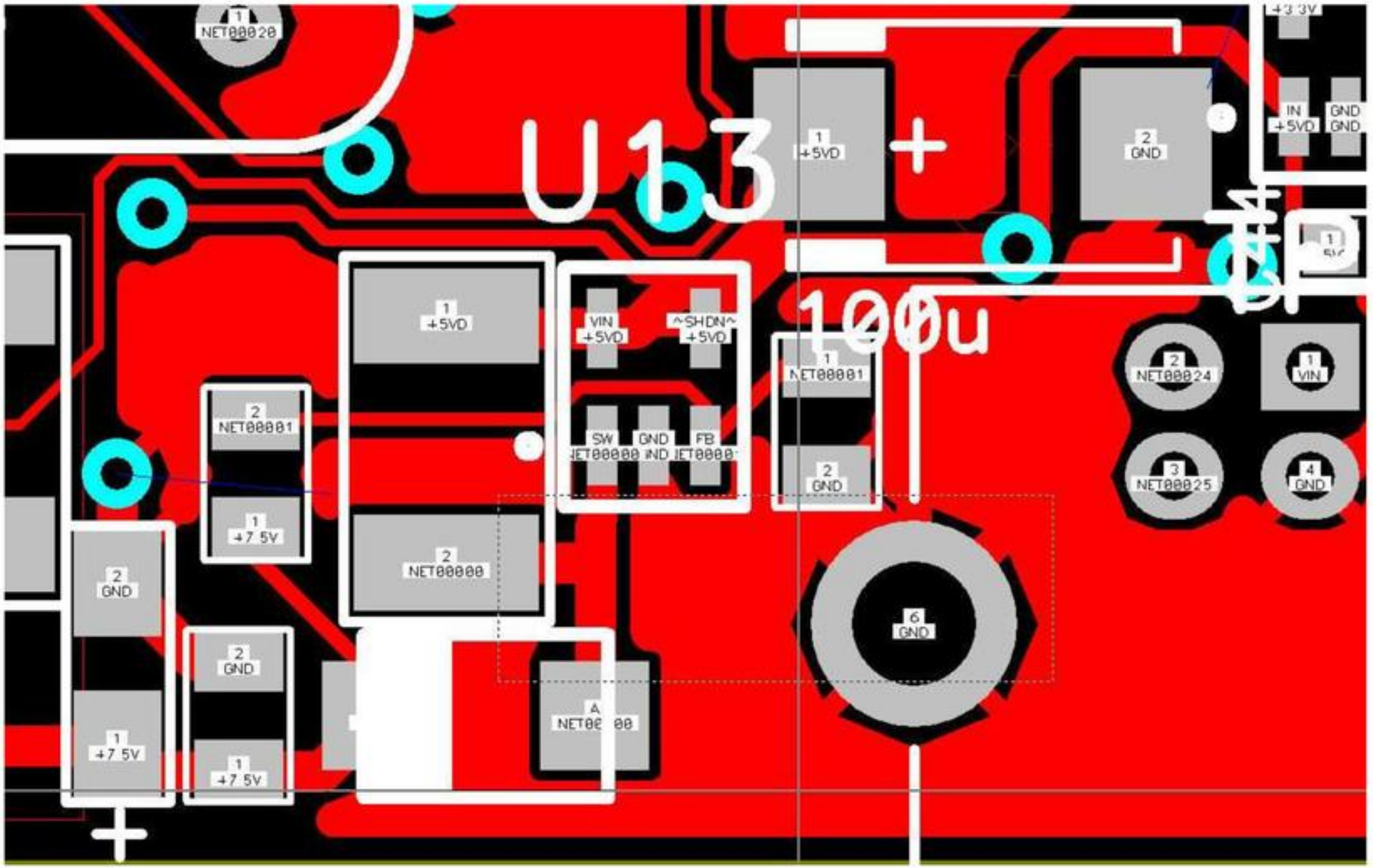
Stikalni DC-DC pretvorniki



Postavitev kondenzatorjev, tokovne zanke



Presluh


U13
1
NET00020
1
+5VD
2
GND
+3.3V
IN
+5VD
GND
GND
1
+5VD
VIN
+5VD
~SHDN~
+5VD
100u
1
NET00001
2
NET00024
1
VIN
2
NET00001
SW
GND
FB
2
GND
3
NET00025
4
GND
1
+7.5V
2
NET00000
2
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6
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2
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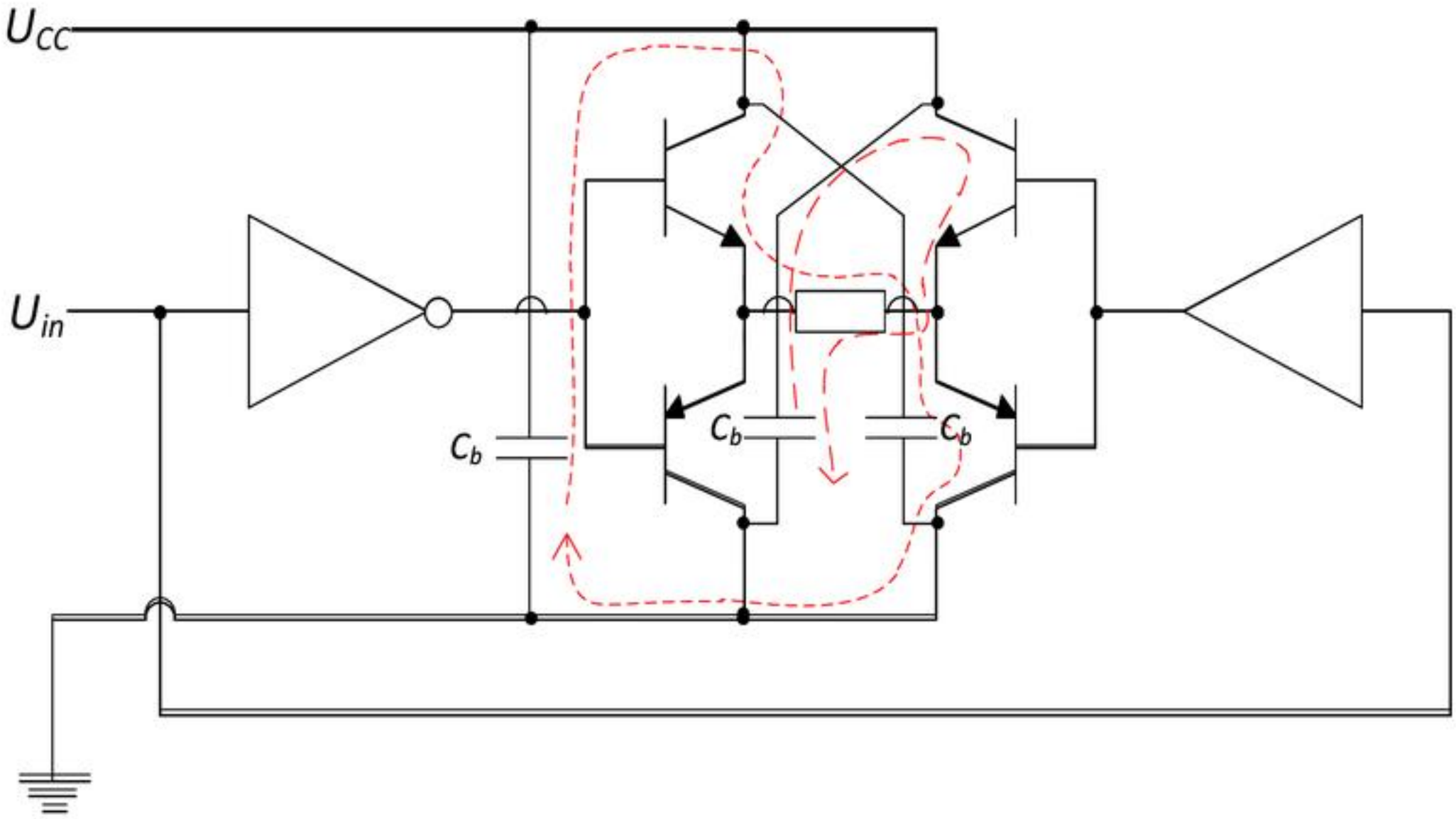
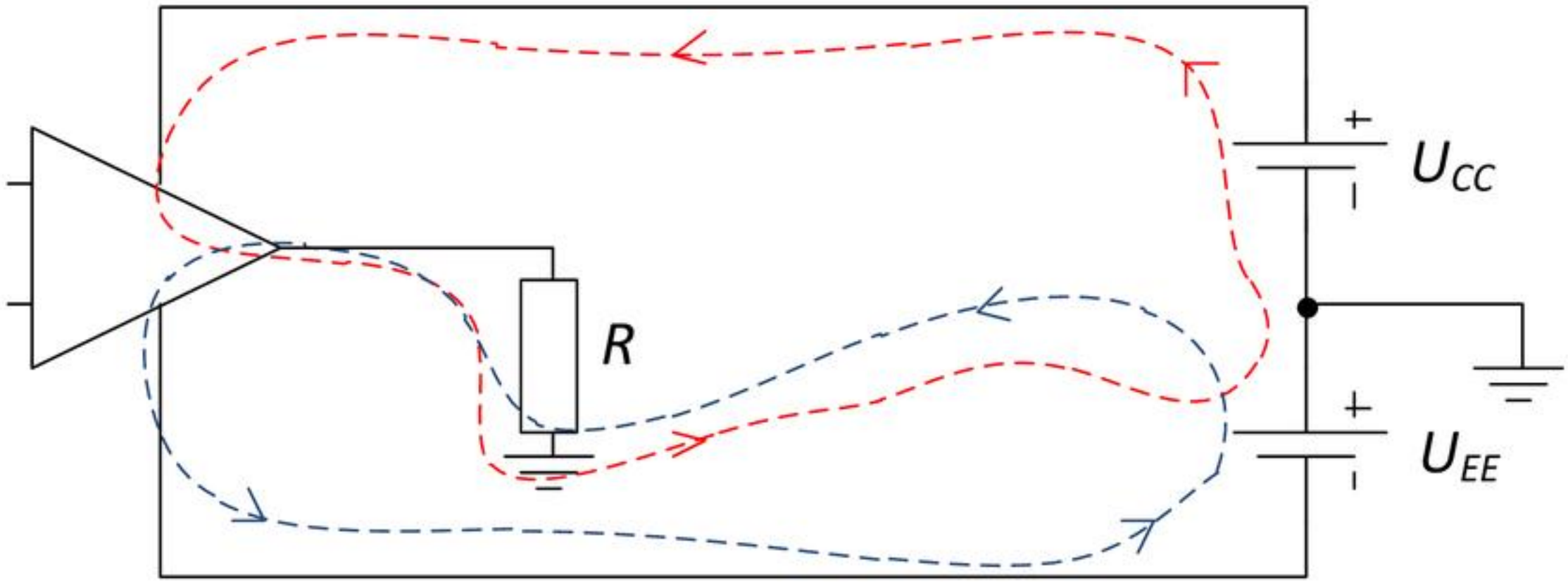
1
+7.5V
1
+7.5V

Postavitev blokirnega kondenzatorja



Postavitev blokirnega kondenzatorja



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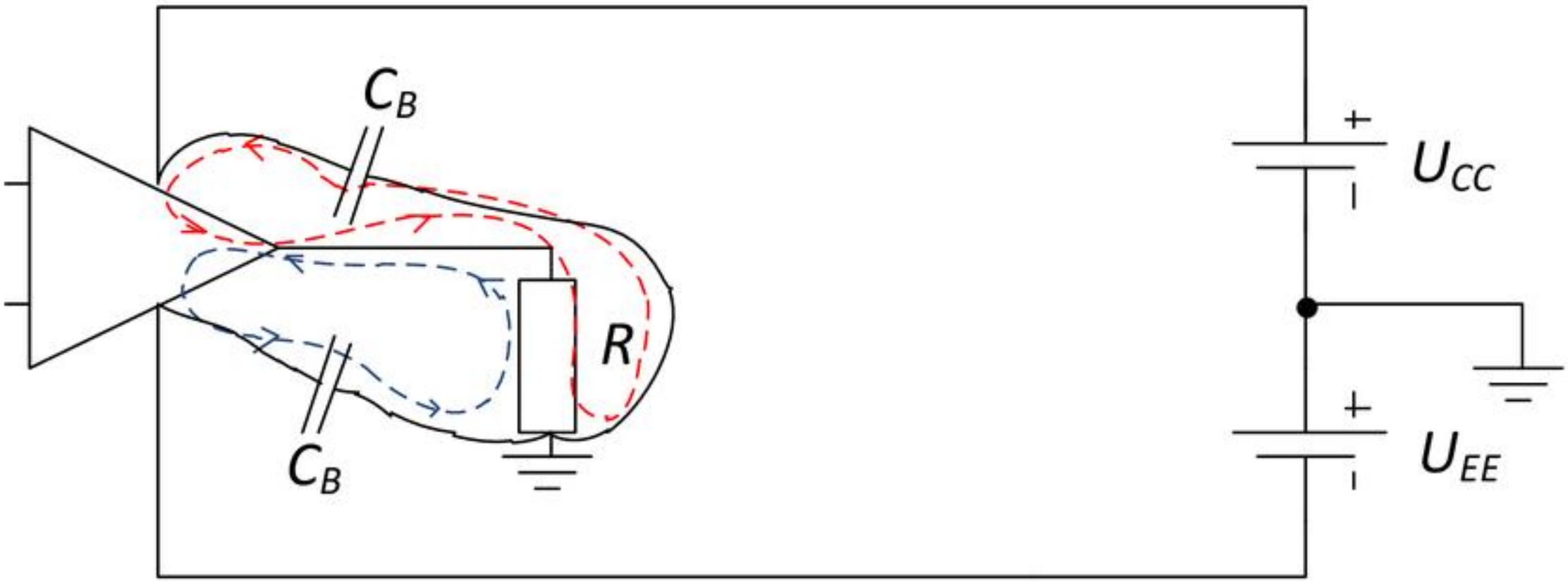
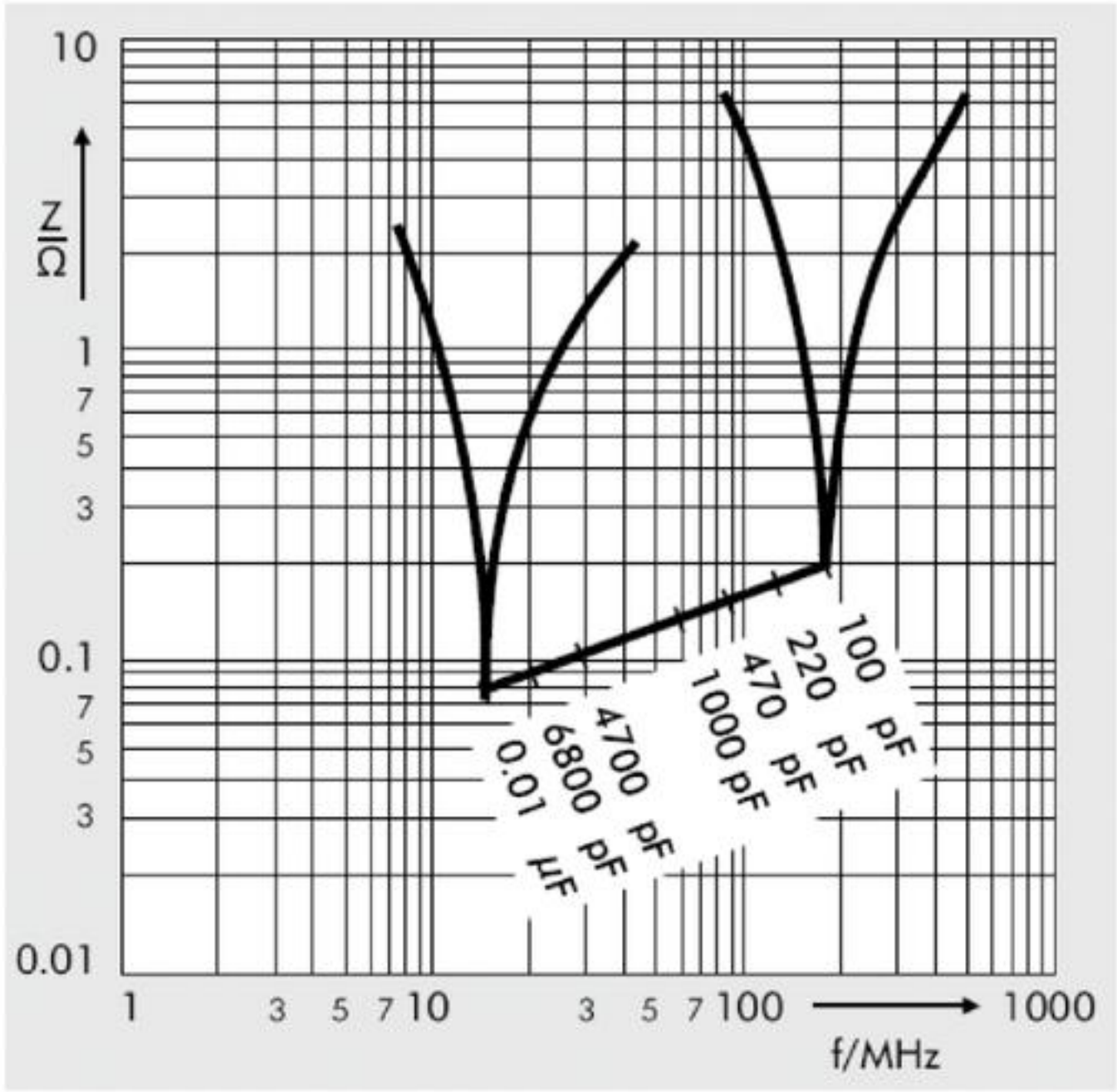
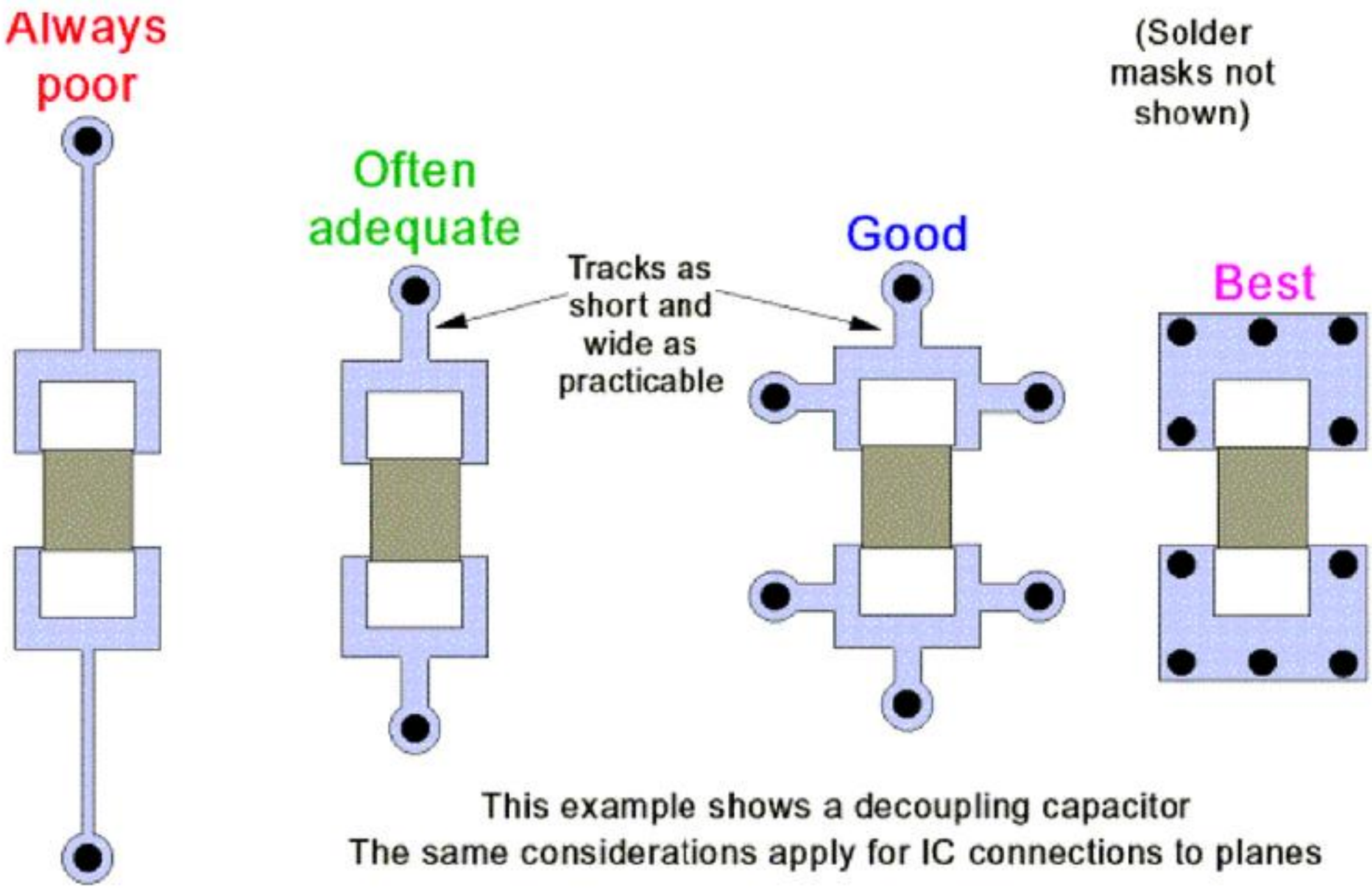


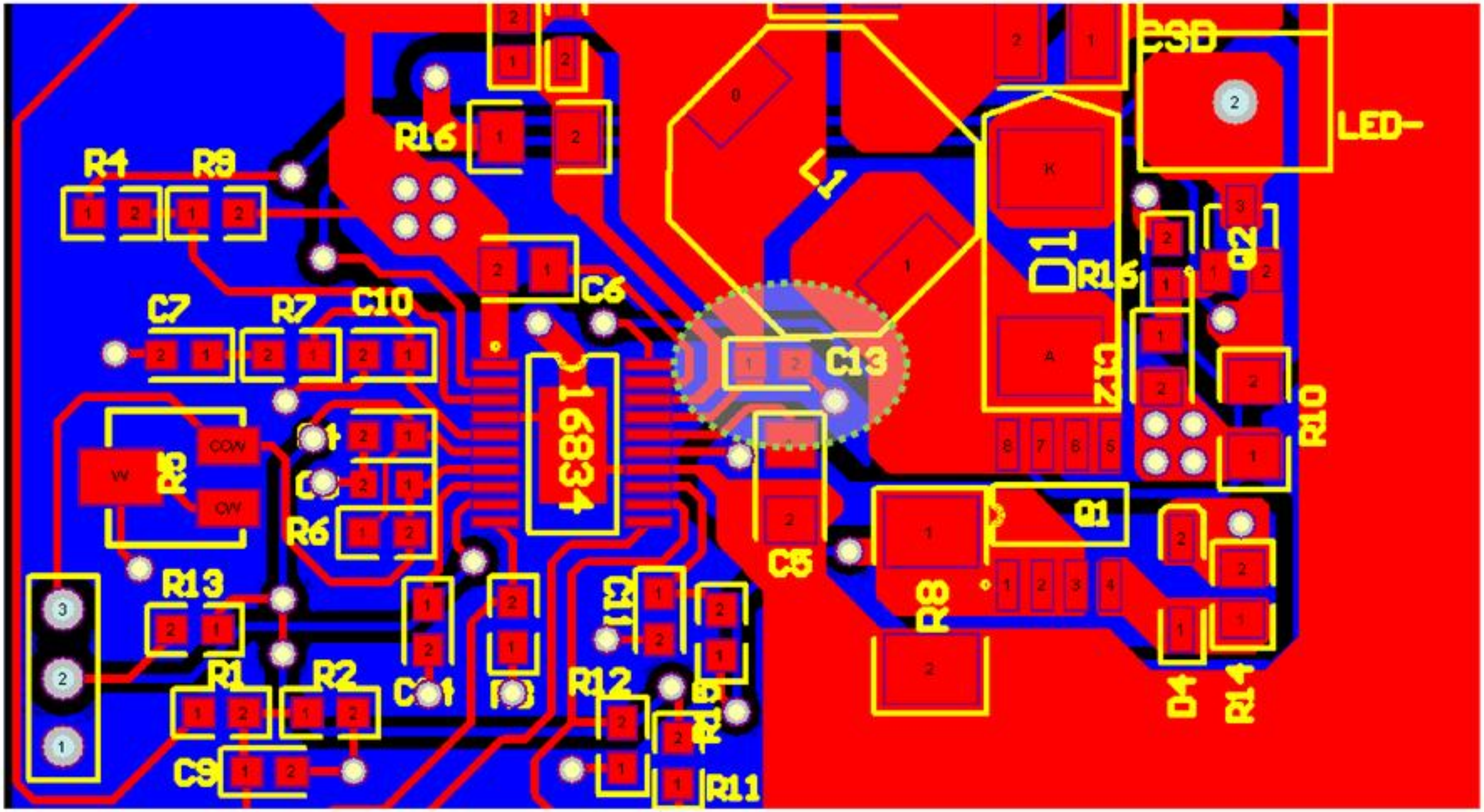
Kondenzator? Tuljava? Oboje!



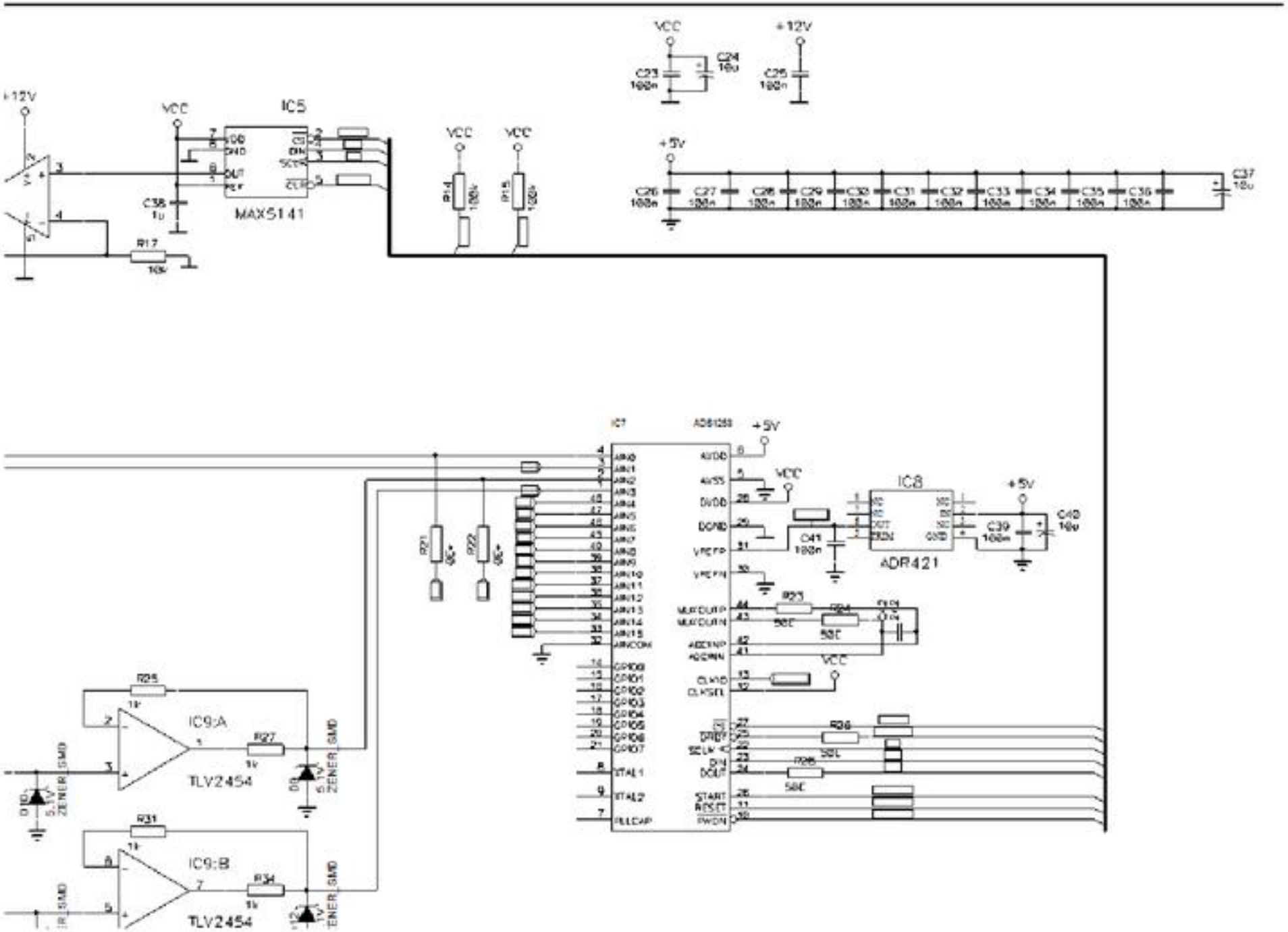
Priključitev blokirnega kondenzatorja



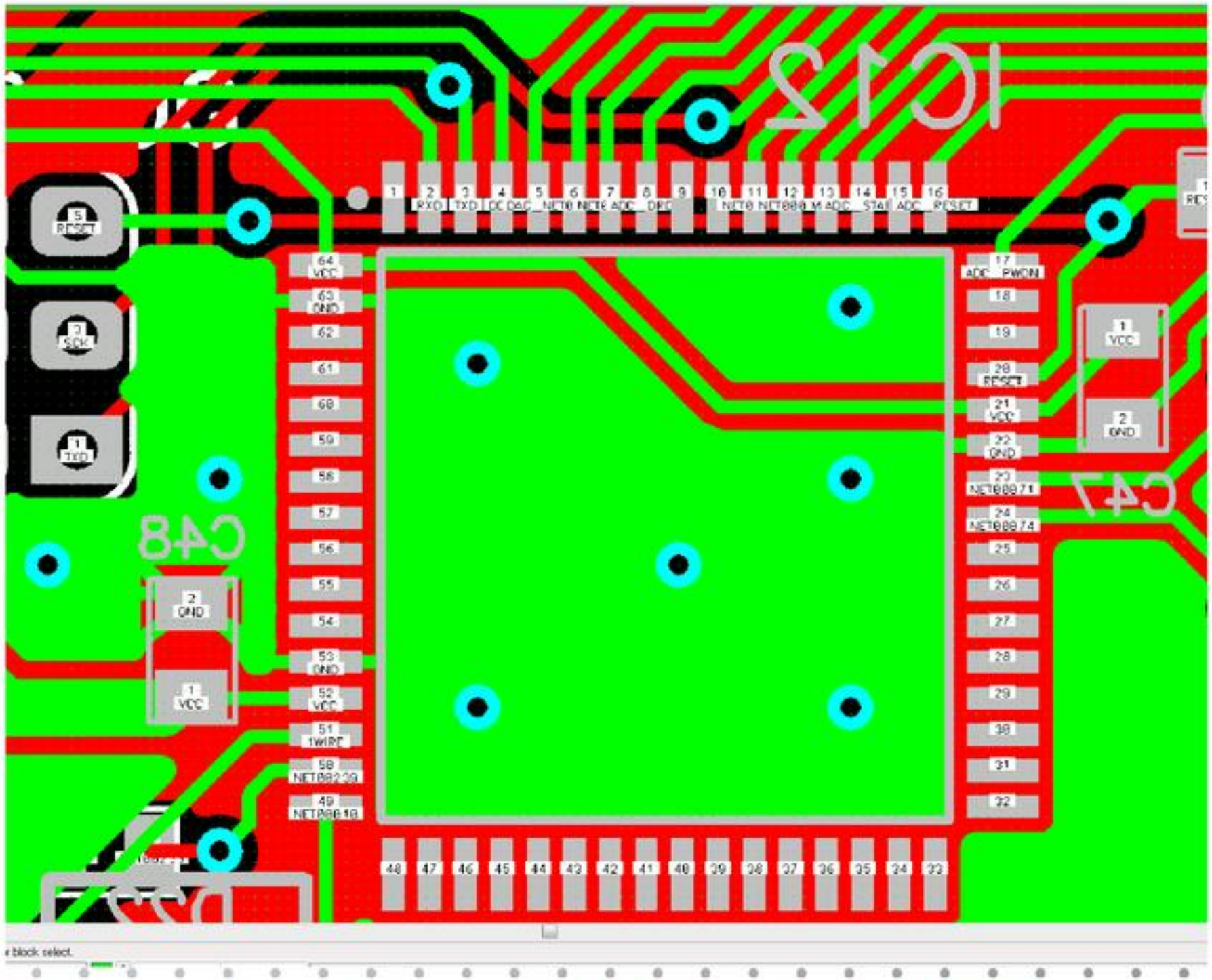
Postavitev blokirnega kondenzatorja



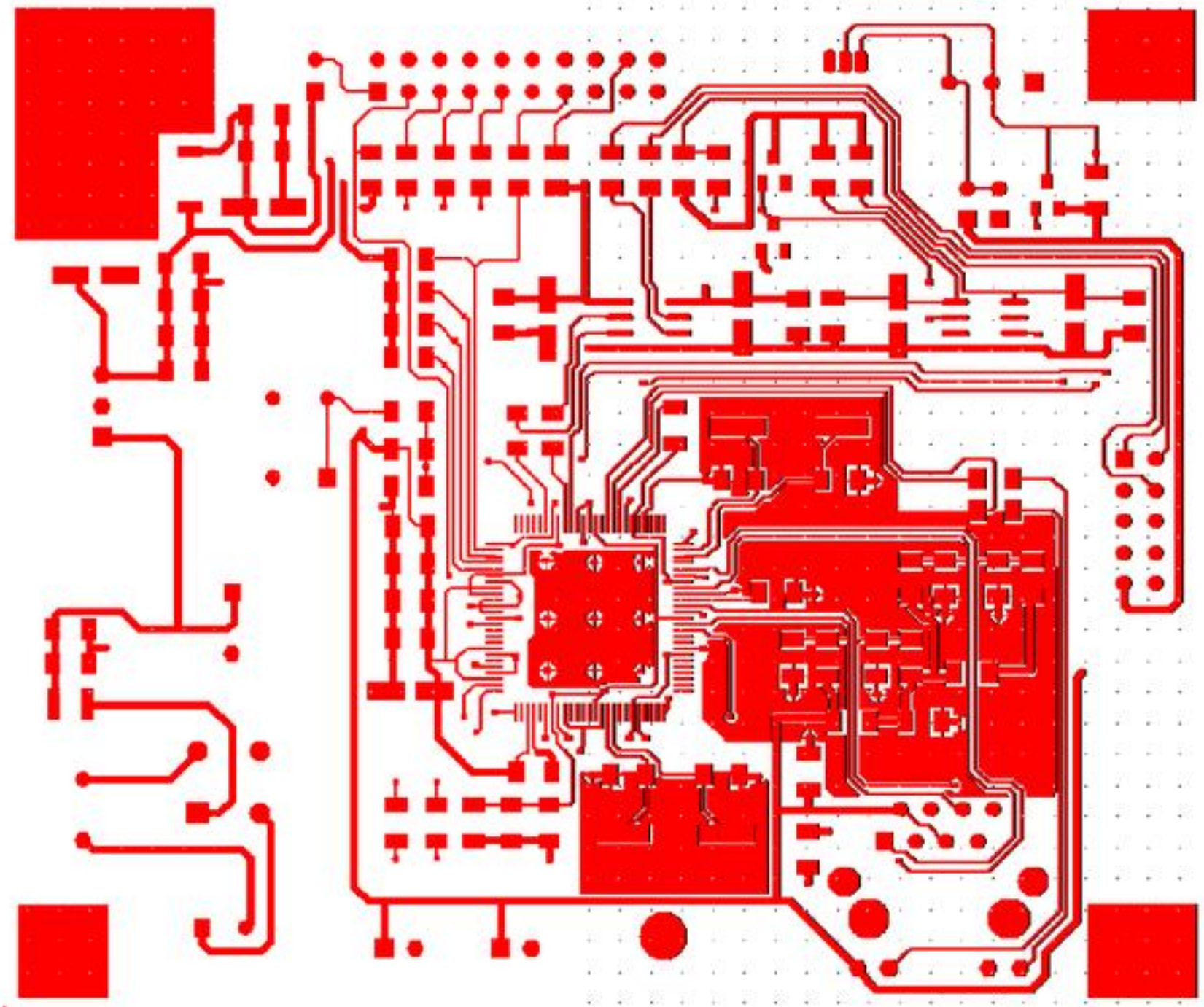
Postavitev blokirnih kondenzatorjev



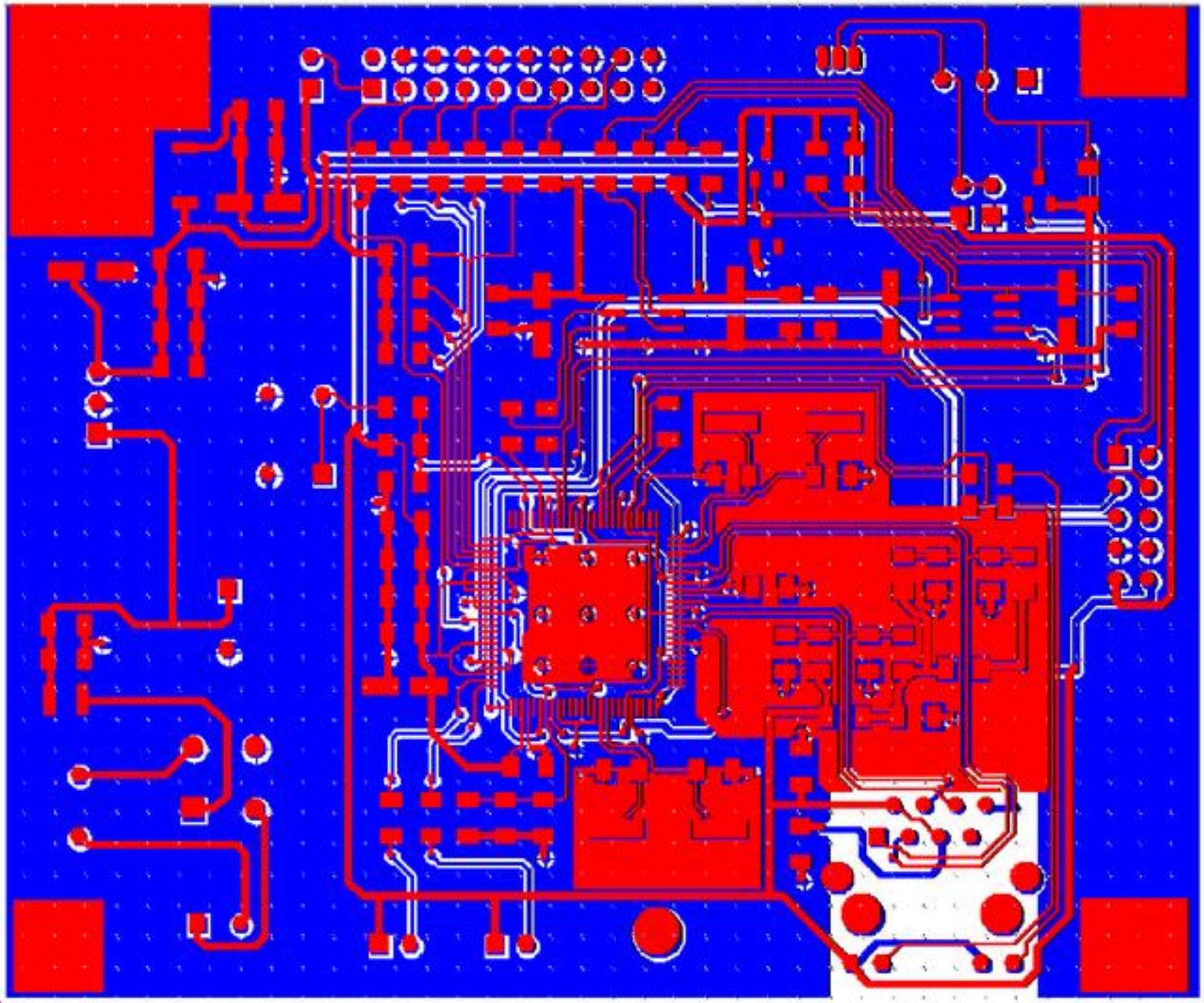
Postavitev blokirnih kondenzatorjev



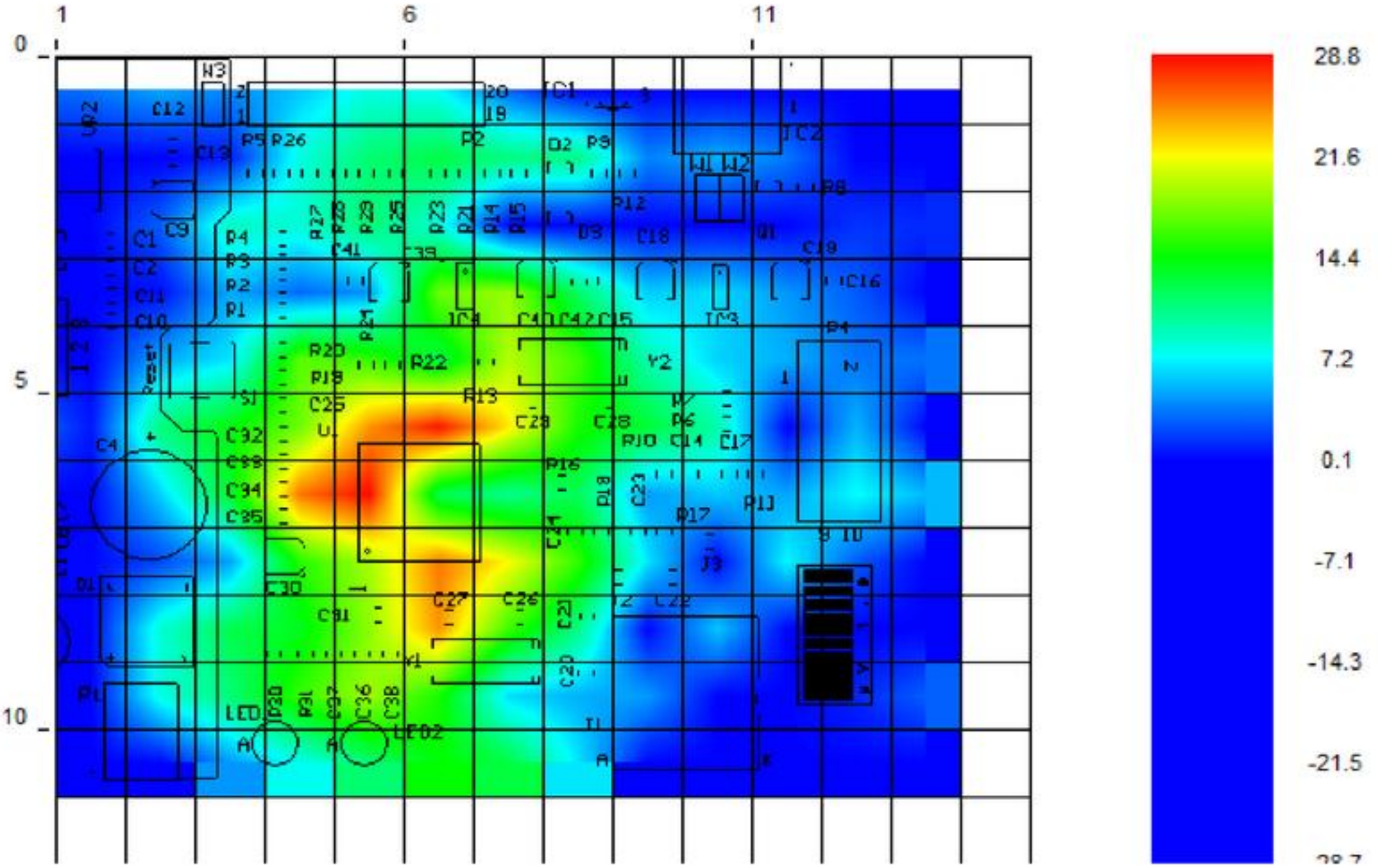
Postavitev blokirnih kondenzatorjev



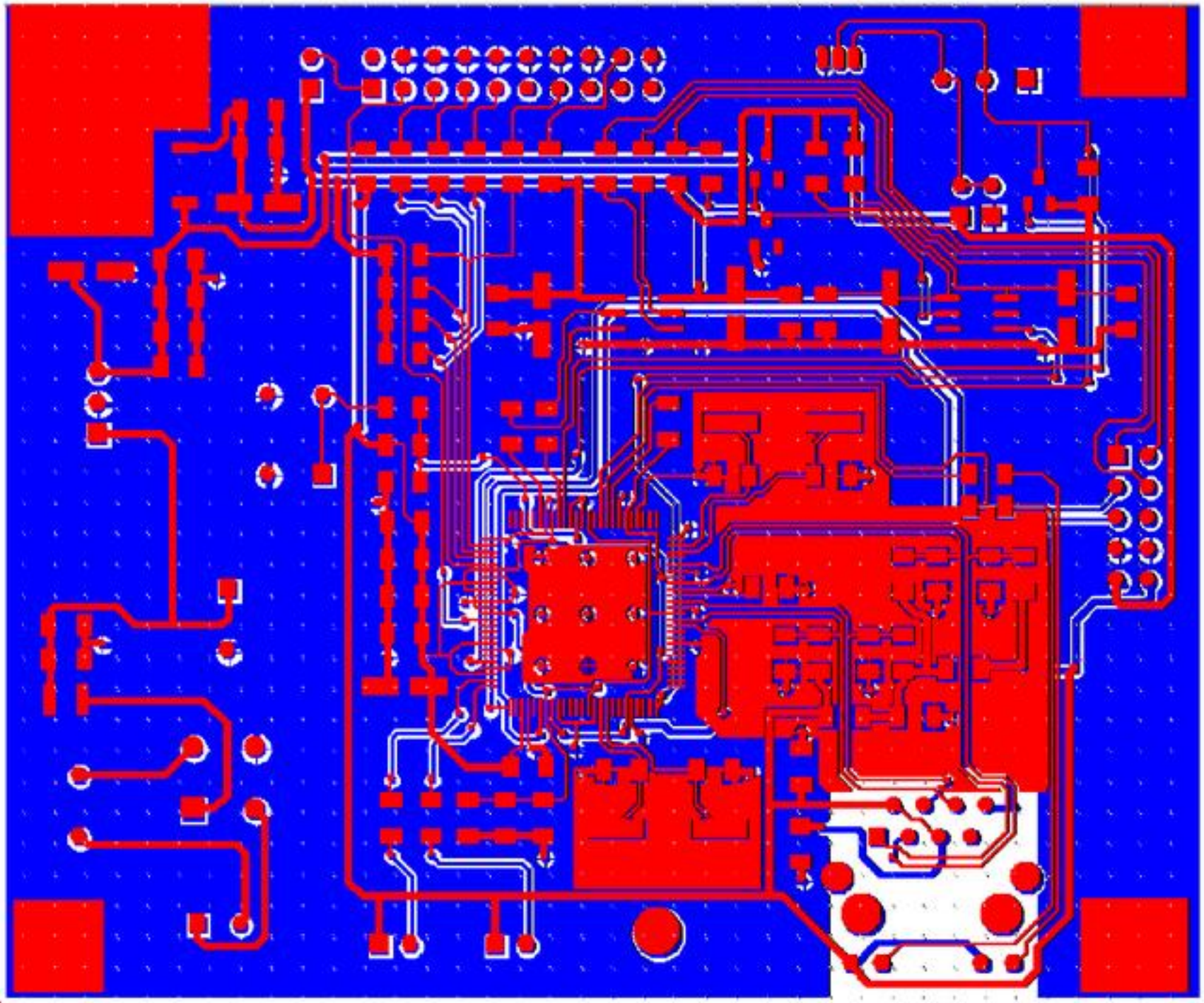
Postavitev blokirnih kondenzatorjev



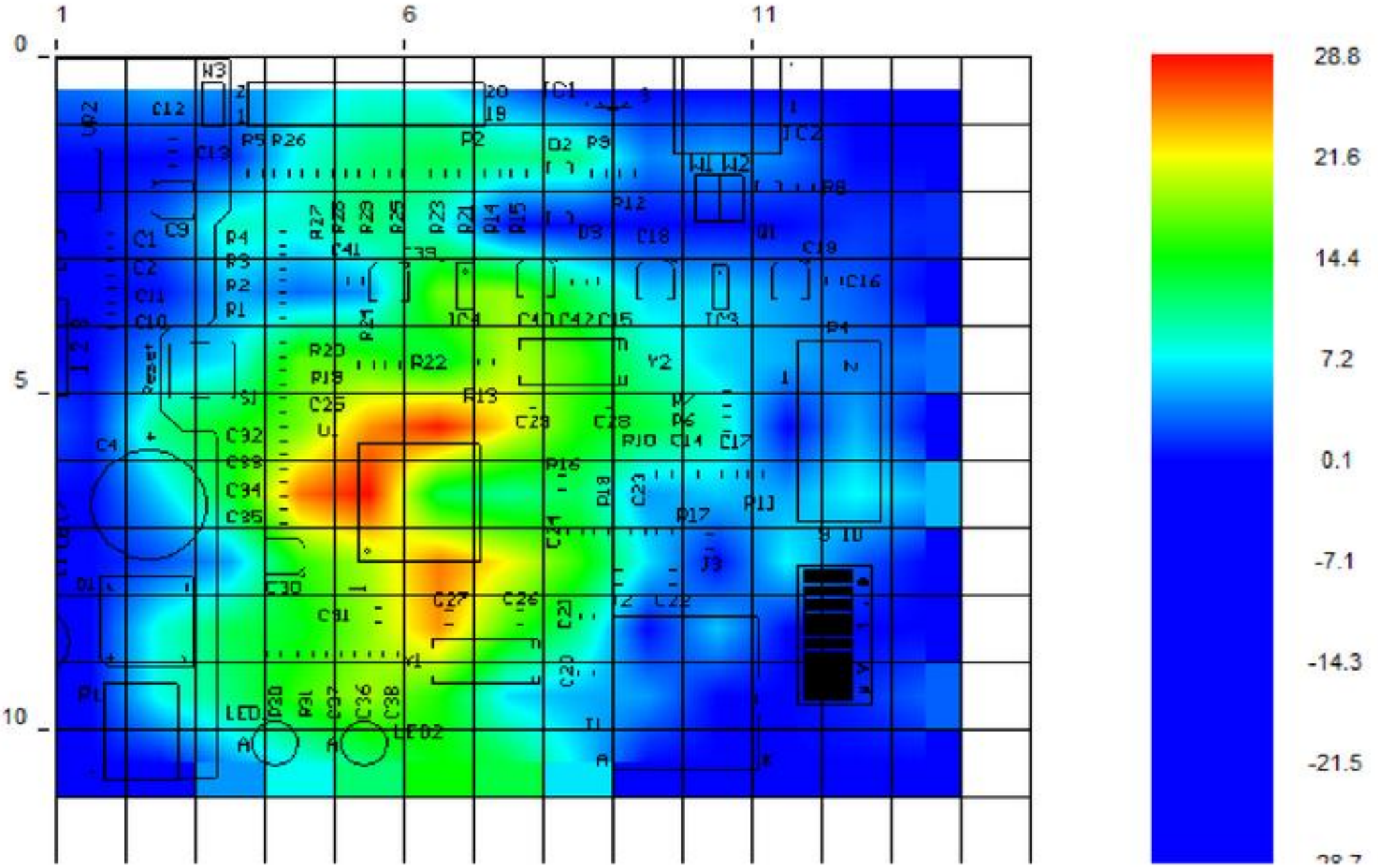
Jakost E polja pri 50 MHz



Postavitev blokirnih kondenzatorjev

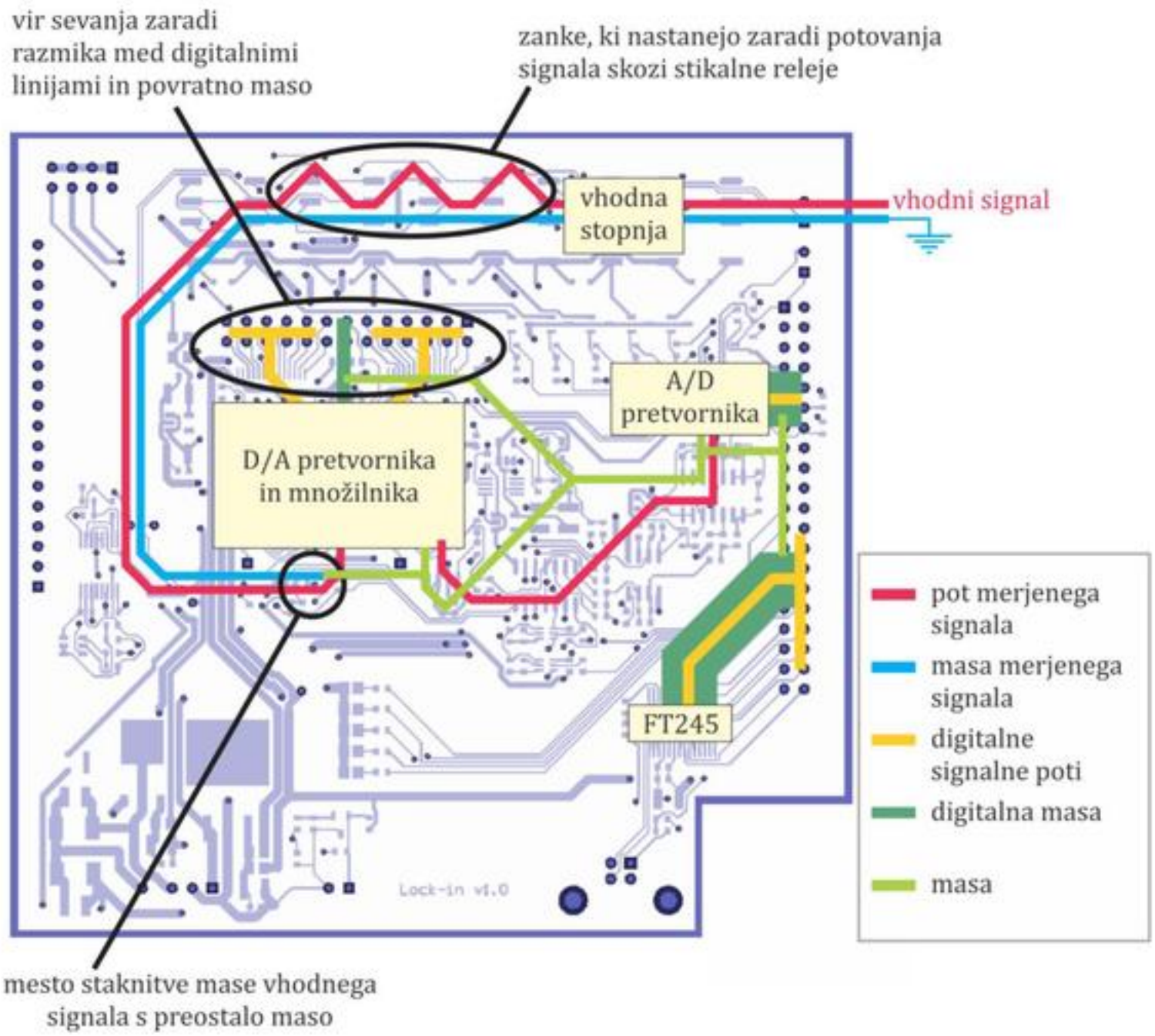


Jakost E polja pri 50 MHz

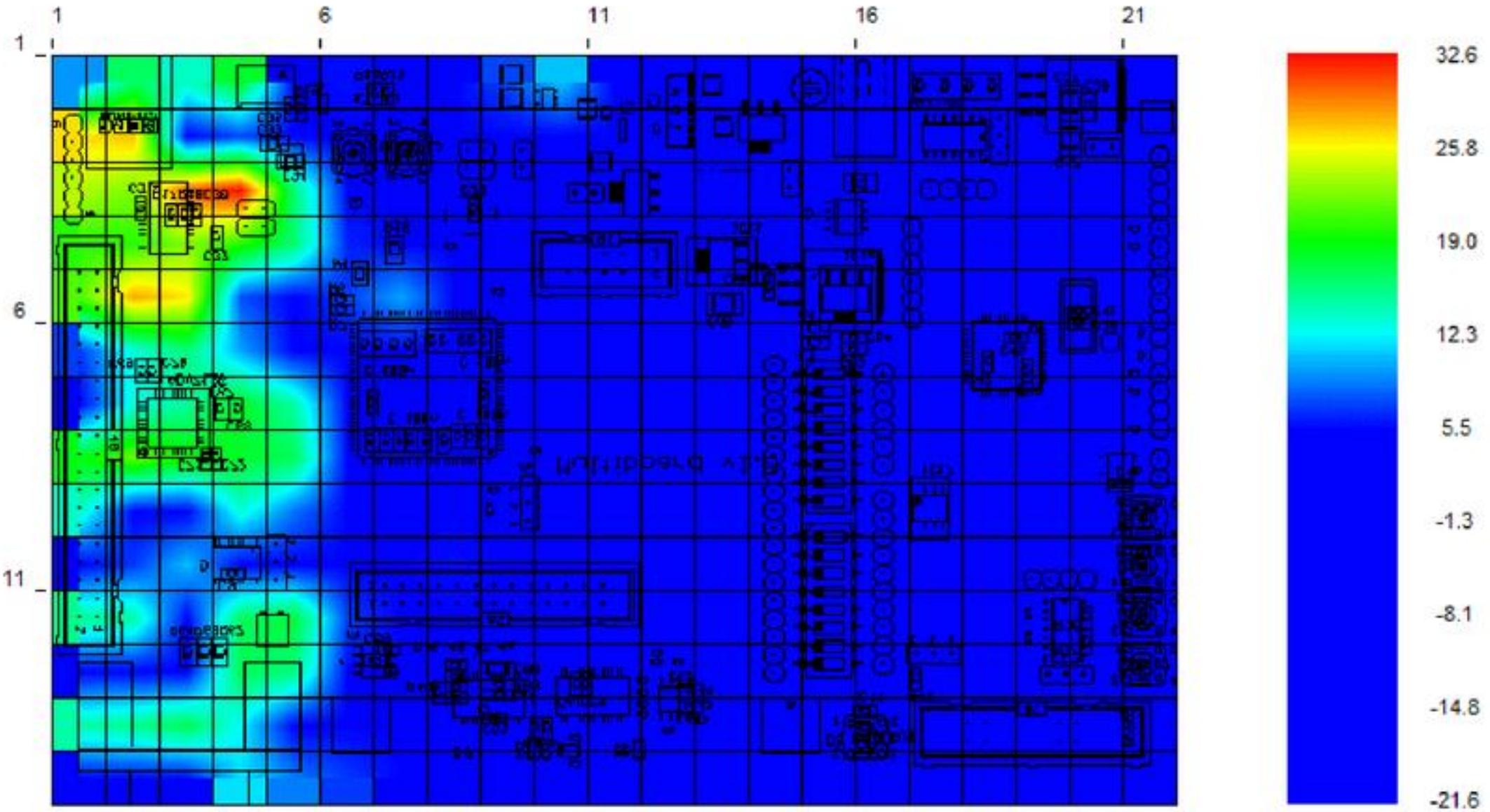


EM scan

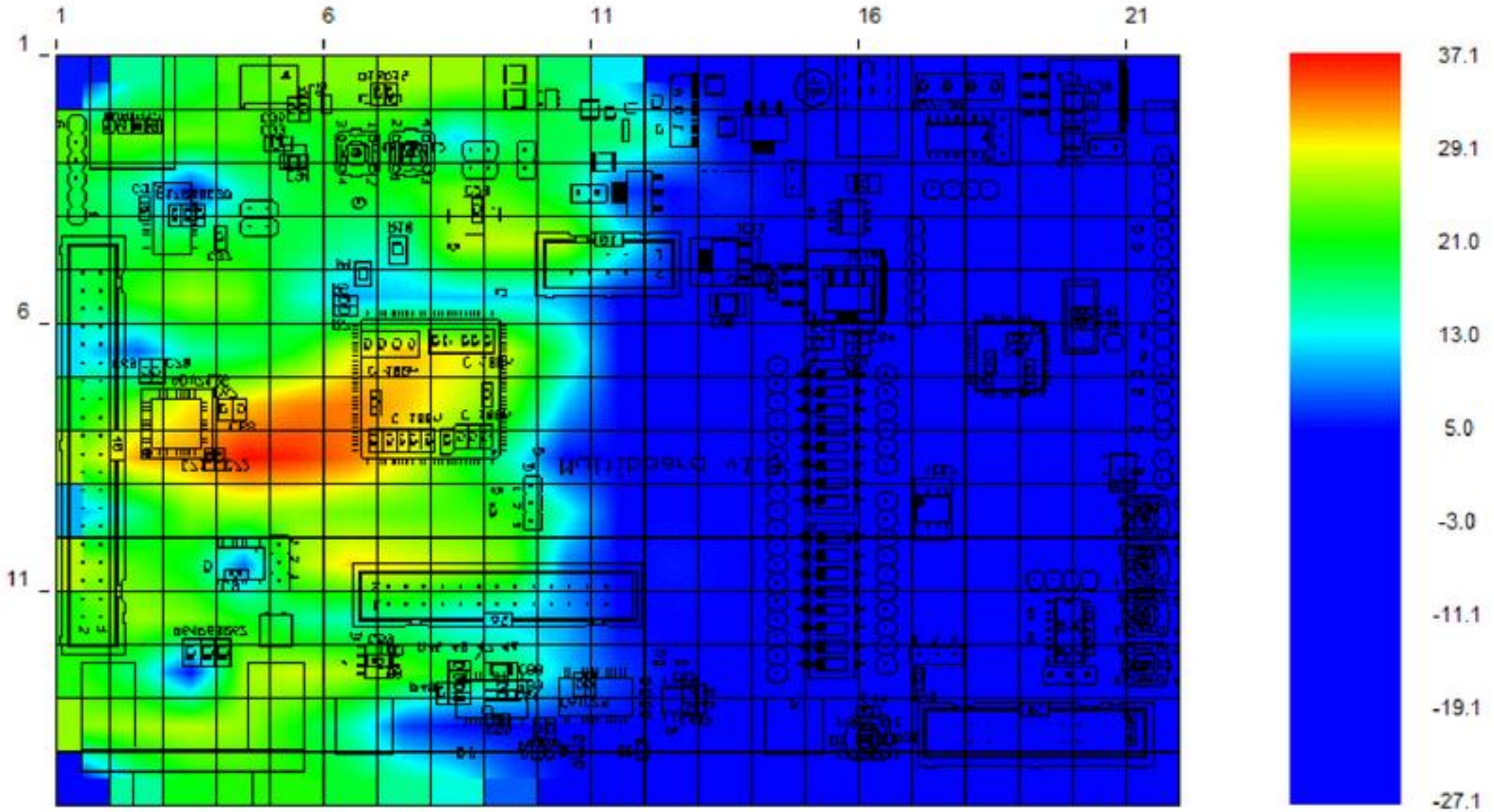
Viri sevanj v digitalno-analognem vezju



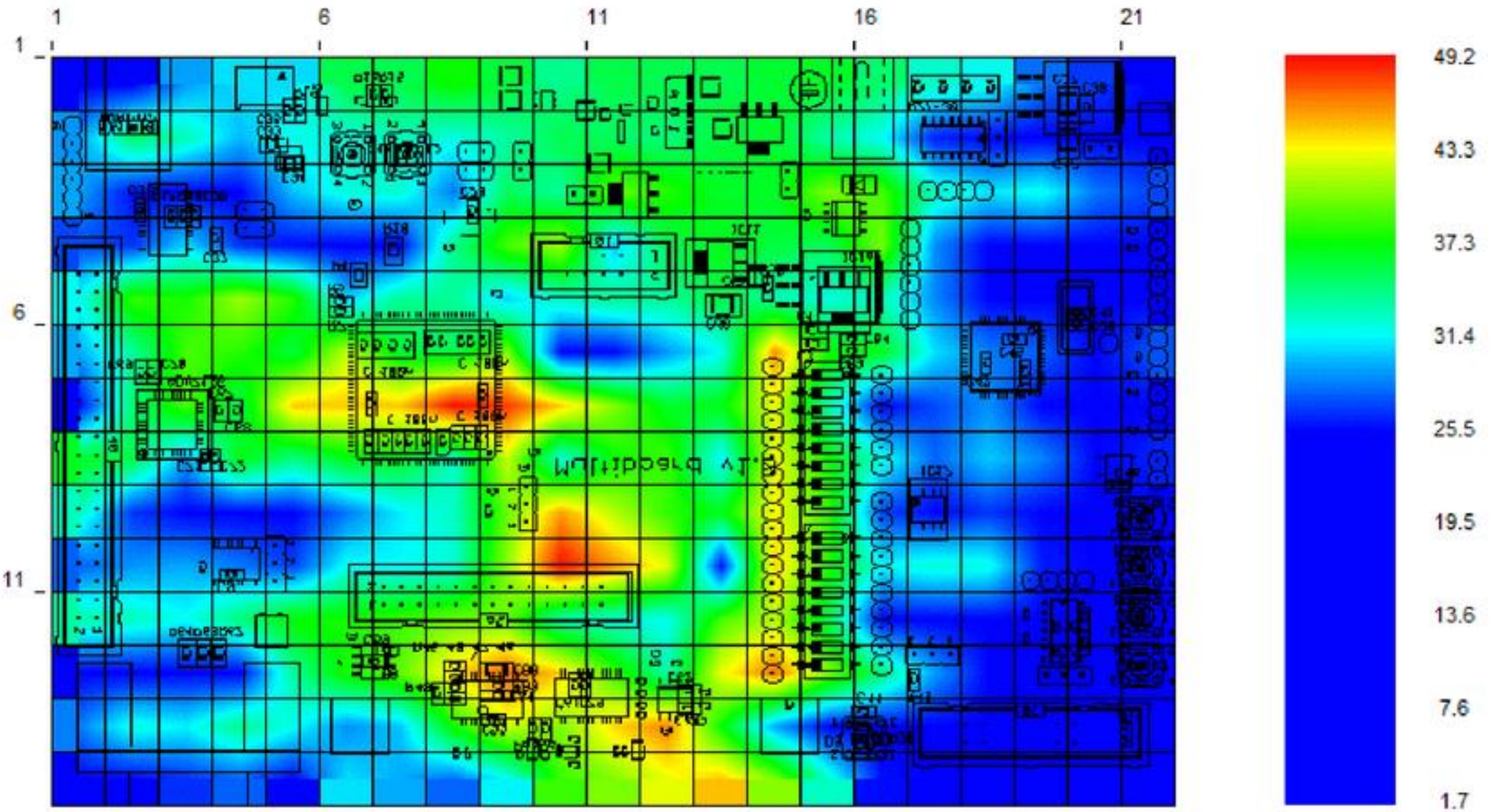
Jakost E polja pri 24 MHz



Jakost E polja pri 32 MHz



Jakost E polja pri 100 MHz



Prijetno branje

- Mark I. Montrose, *Printed Circuit Board Design Techniques for EMCComplience*, Wiley-Interscience IEEE, ISBN 0-7803-5376-5, New York, 2000.
- Howard W. Johnson, *High-speed digital design*, Prentice-Hall Inc., Upper SaddleRiver, NJ, ISBN 0-13-395724-1, 1993.
- A. E. Ward, J. A. S. Angus, *Electronic Product Design*, Chapman & Hall, ISBN 0-412-63200-4, London, 1996.
- C.A. Harper, *Electronic Packaging and Interconnection Handbook*, 3rd edition, The McGraw-Hill Companies, Inc.
- Rao R. Tummala, Ed., "Fundamentals of Microsystem Packaging", McGraw Hill, New York, 2001.
- Henry W. Ott, *Electromagnetic Compatibility Engineering*, J. Wiley & Sons, ISBN 978-0-470-18930-6,2009.
- http://lpvo.fe.uni-lj.si/izobrazevanje/2-stopnja-un/konstruiranje-elektronskih-naprav-ken/