Za hrotem digitální tužky: Fyzika, elektronika a elektromagnetická rezonance

Robin Josef Šafařík, 2026



Zdroj: sc04.alicdn.com



Zdroj: prod.website-files.com



Zdroj: heureka.group



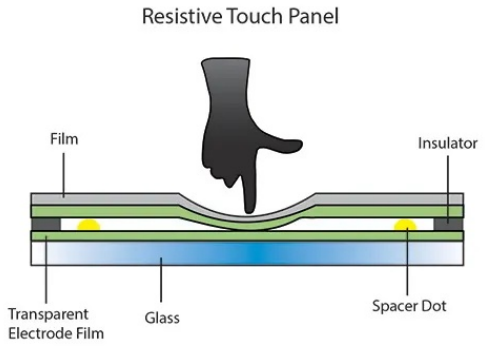
Zdroj: alza.cz





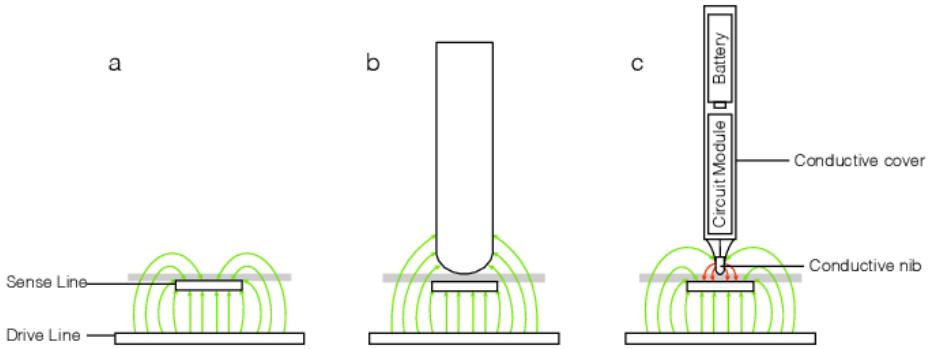
Zdroj: business.hanvonugee.com

Technologie snímání rukopisu



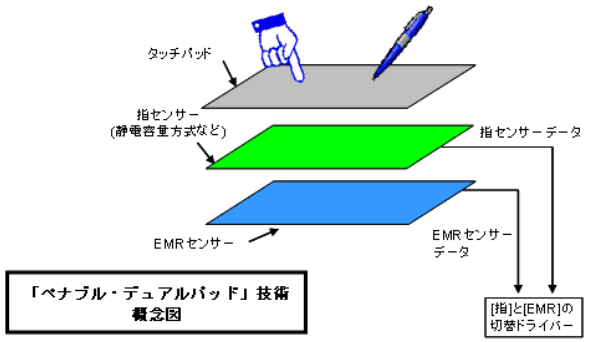
Zdroj: ldycdn.com

Rezistivní (odporová)



Zdroj: researchgate.net

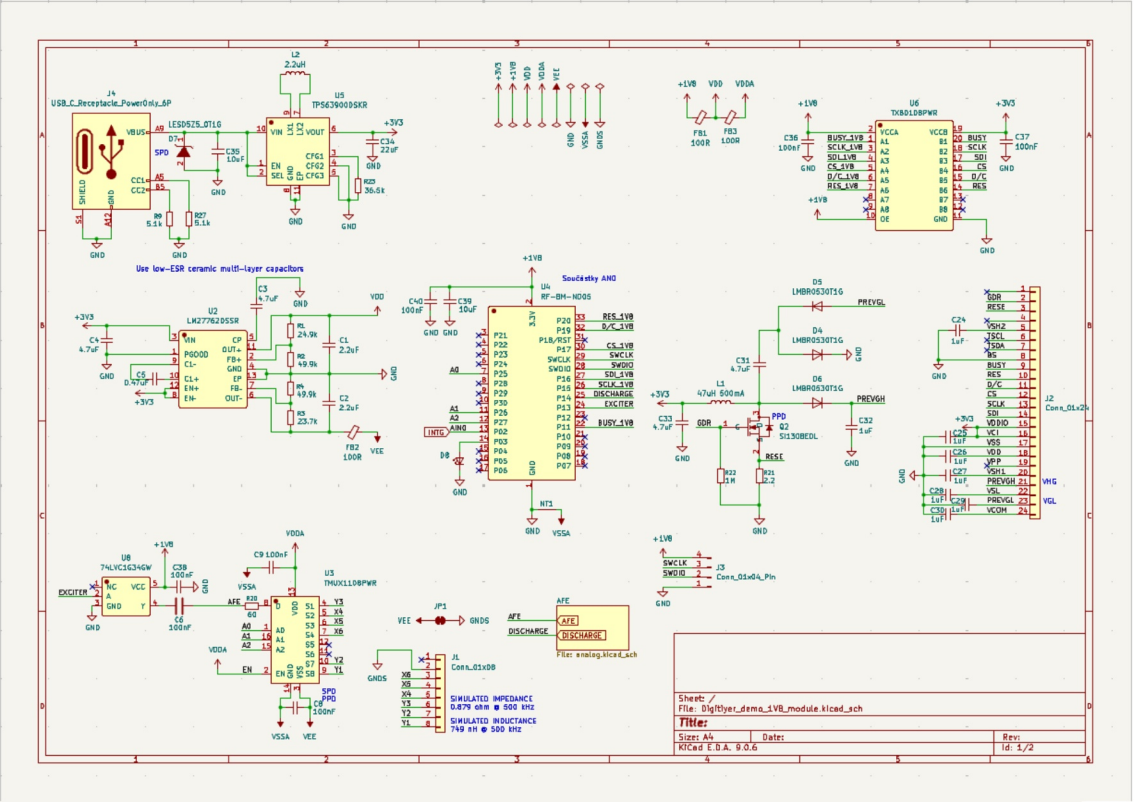
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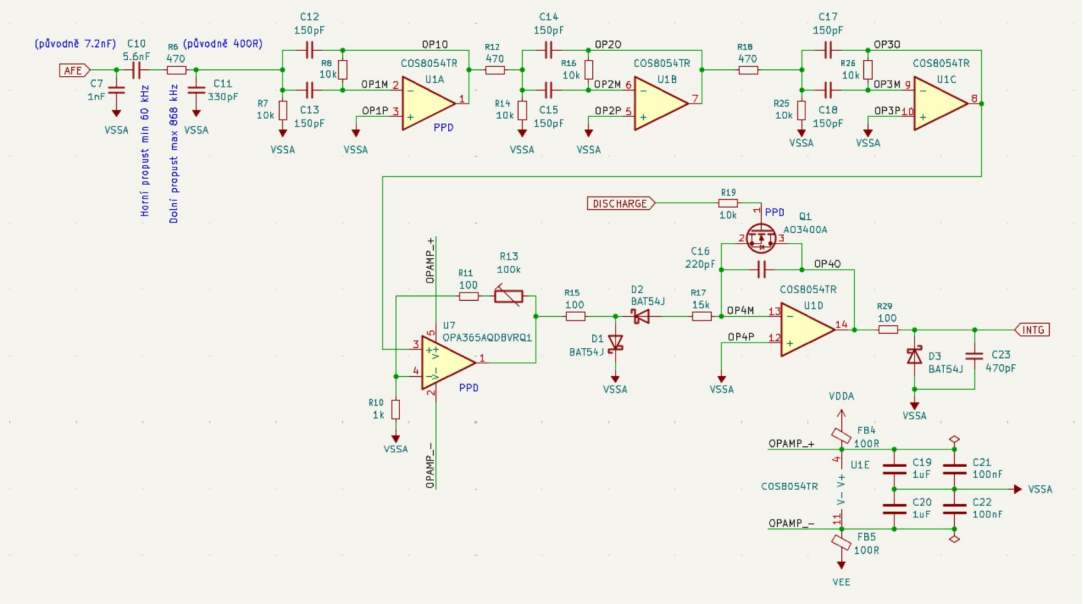


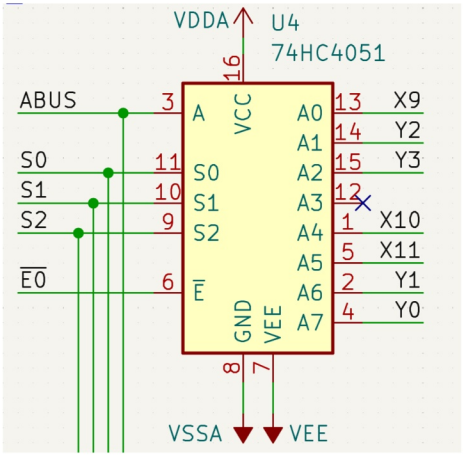
Zdroj: tablet.wacom.co.jp

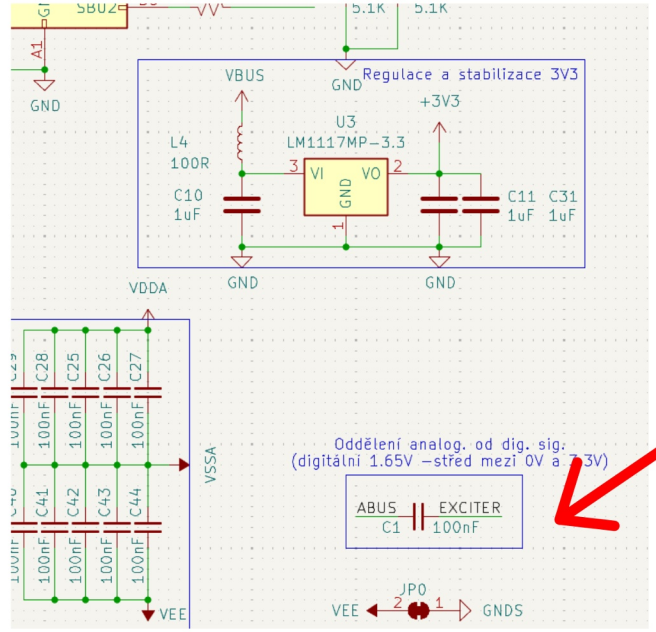
EMR = elmag. rezonanční

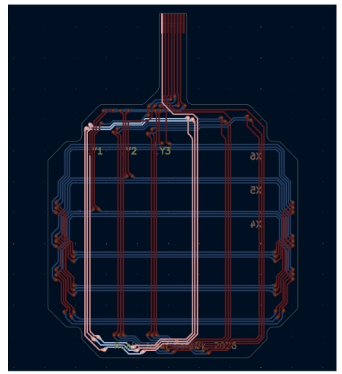
... infračervená laserová, optická, akustická, atd. atd.

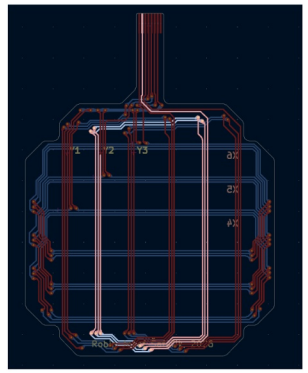

Use low-ESR ceramic multi-layer capacitors
Součástky ANO
SIMULATED IMPEDANCE
0.879 ohm @ 500 kHz
SIMULATED INDUCTANCE
749 nH @ 500 kHz
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Rev:
KiCad E.D.A. 9.0.6
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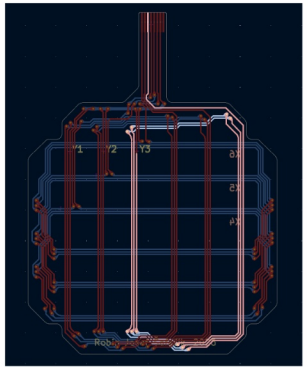

(původně 7.2nF)
(původně 400R)
Horní propust min 60 kHz
Dolní propust max 868 kHz
COS8054TR
OPA365AQDBVRQ1
BAT54J
AO3400A
PPD
VSSA
VDDA
VEE
INTG
DISCHARGE

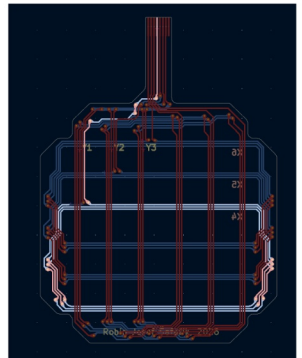

VDDA
U4
74HC4051
ABUS
S0
S1
S2
E0
X9
Y2
Y3
X10
X11
Y1
Y0
VSSA
VEE

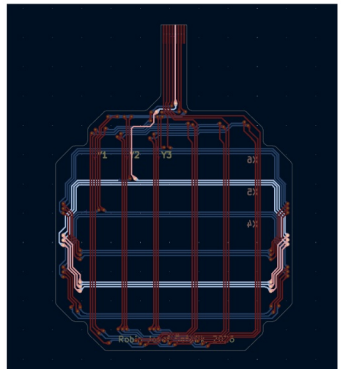

Regulace a stabilizace 3V3
VBUS
GND
+3V3
U3
LM1117MP-3.3
L4
100R
C10
1uF
C11
1uF
C31
1uF
VDDA
VSSA
VEE
Oddělení analog. od dig. sig.
(digitální 1.65V –střed mezi 0V a 3.3V)
ABUS
EXCITER
C1
100nF
JP0
VEE
GNDS

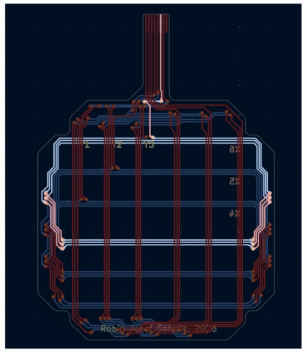


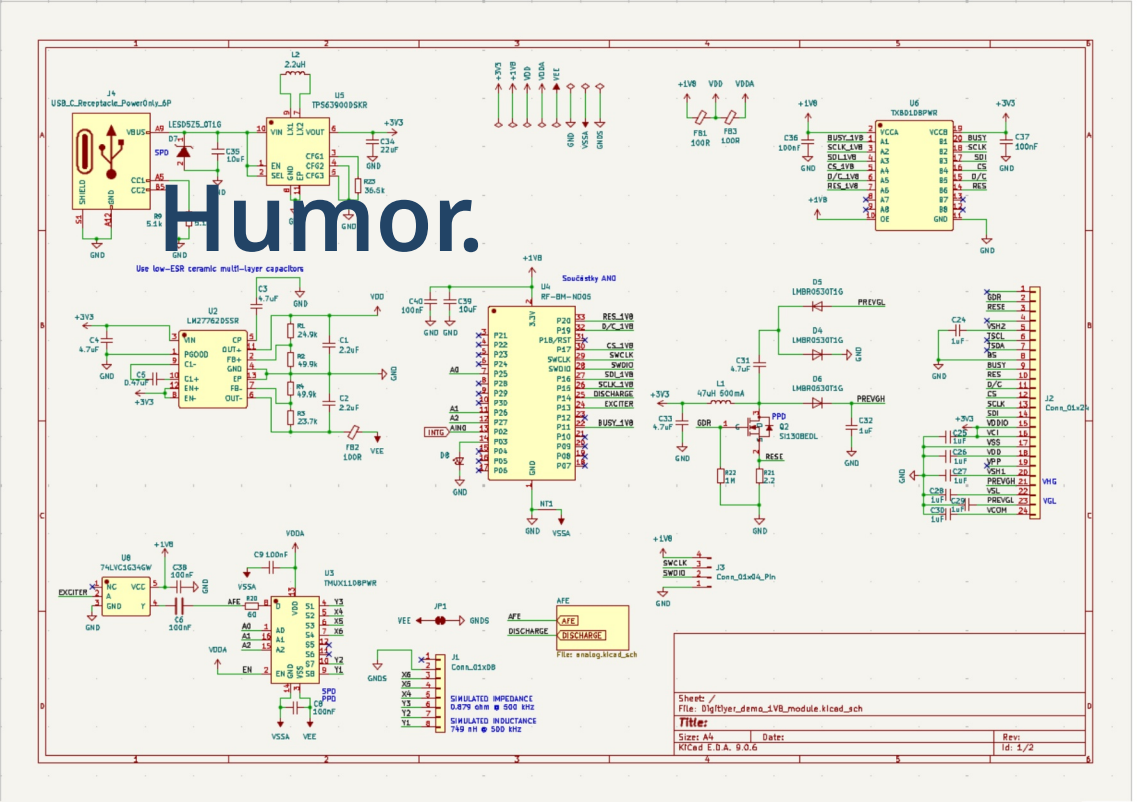


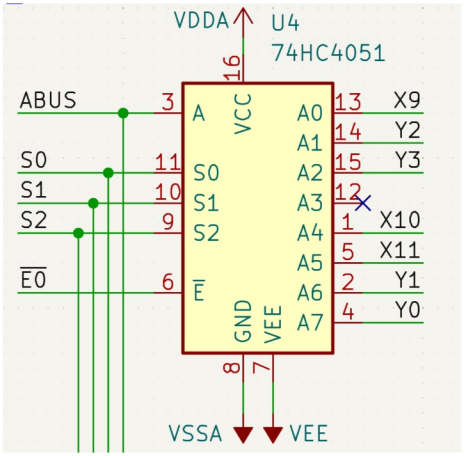


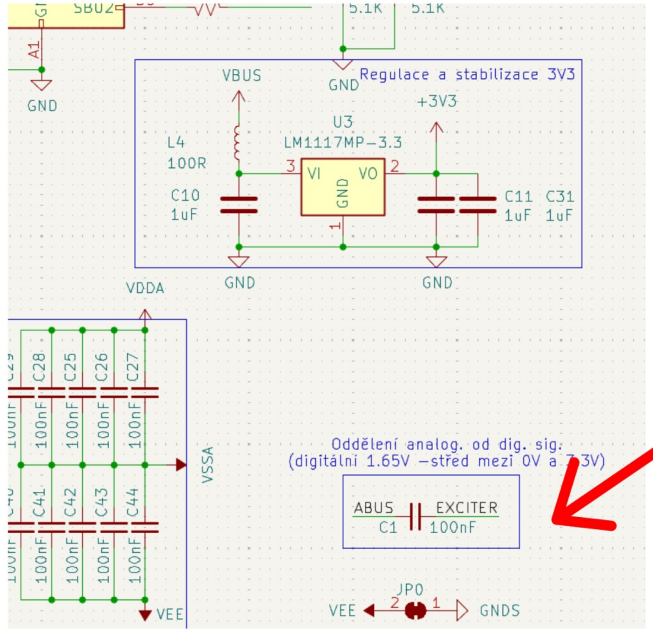


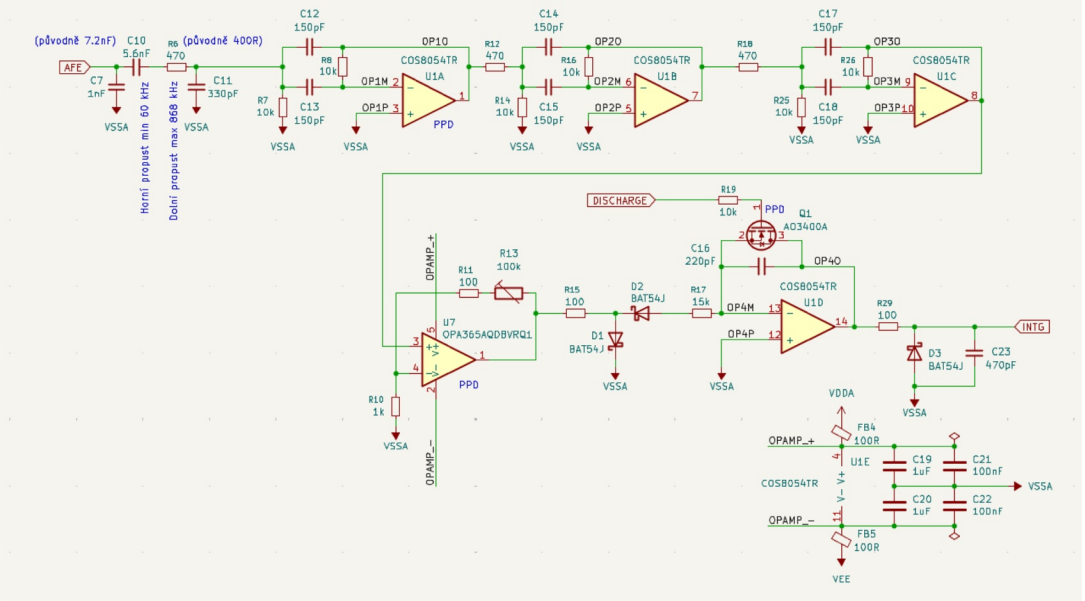


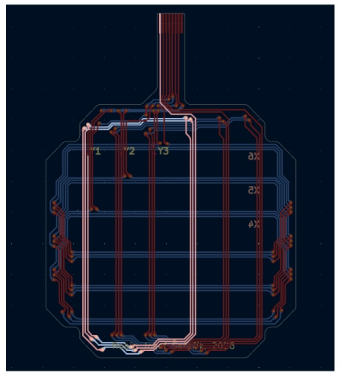


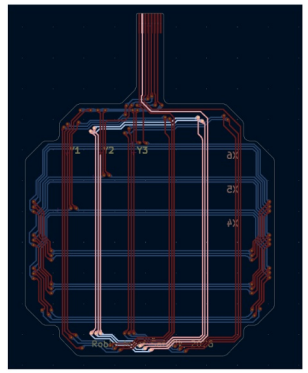

Humor.
Use low-ESR ceramic multi-layer capacitors
Sheet: /
File: Digityer_demo_1V8_module.kicad_sch
Title:
Size: A4
Date:
Rev:
KiCad E.D.A. 9.0.6
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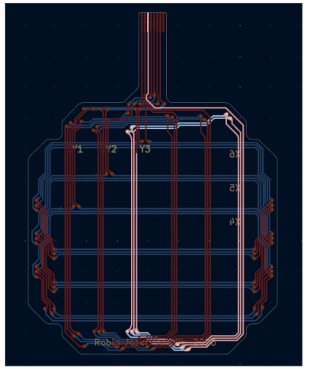

VDDA
U4
74HC4051
ABUS
S0
S1
S2
E0
A0
A1
A2
A3
A4
A5
A6
A7
X9
Y2
Y3
X10
X11
Y1
Y0
VCC
GND
VEE
VSSA

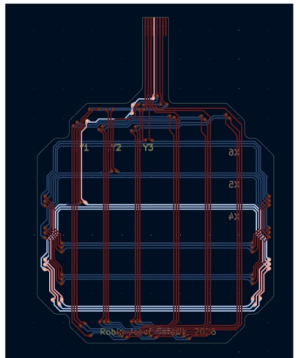

Regulace a stabilizace 3V3
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GND
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U3
LM1117MP-3.3
L4
100R
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1uF
C11
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VDDA
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VEE
Oddělení analog. od dig. sig.
(digitální 1.65V –střed mezi 0V a 3.3V)
ABUS
C1
EXCITER
100nF
JP0
VEE
GNDS

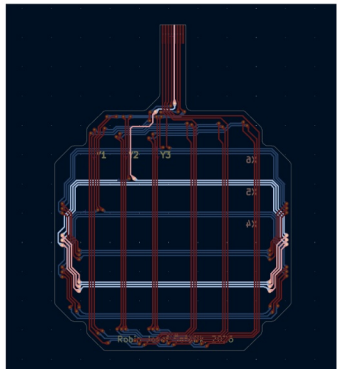

(původně 7.2nF)
(původně 400R)
AFE
C10
5.6nF
R6
470
C7
1nF
C11
330pF
Horní propust min 60 kHz
Dolní propust max 868 kHz
VSSA
C12
150pF
R8
10k
R7
10k
C13
150pF
OP1O
OP1M
OP1P
COS8054TR
U1A
PPD
R12
470
C14
150pF
R16
10k
R14
10k
C15
150pF
OP2O
OP2M
OP2P
U1B
R18
470
C17
150pF
R26
10k
R25
10k
C18
150pF
OP3O
OP3M
OP3P
U1C
DISCHARGE
R19
10k
Q1
AO3400A
C16
220pF
OP4O
OP4M
OP4P
U1D
R17
15k
R13
100k
R11
100
R15
100
D2
BAT54J
D1
BAT54J
U7
OPA365AQDBVRQ1
OPAMP_+
OPAMP_−
R10
1k
R29
100
D3
BAT54J
C23
470pF
INTG
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C21
100nF
C22
100nF

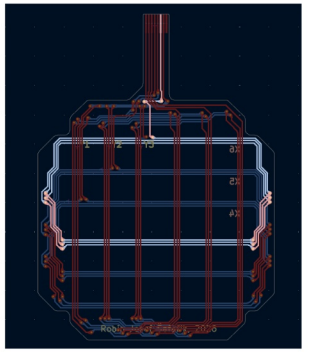






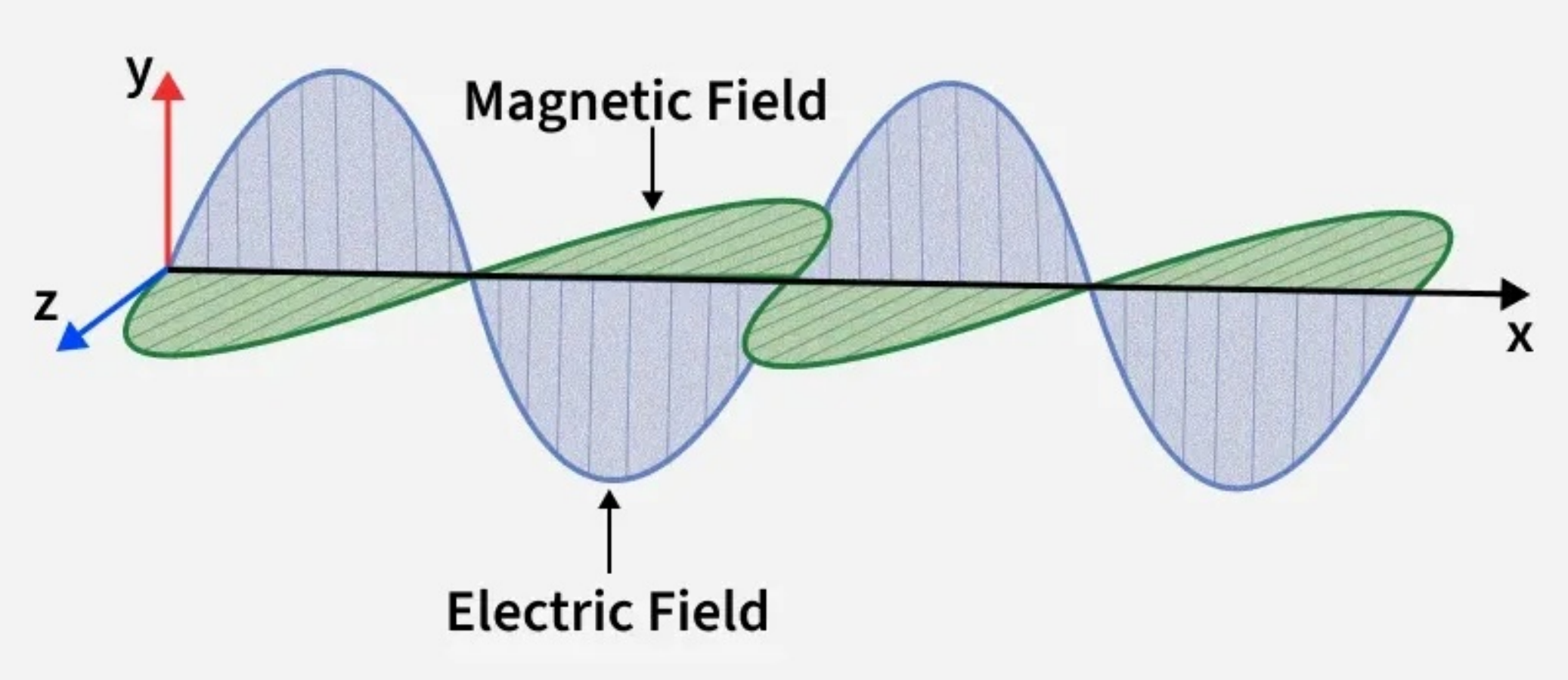






Fyzika za EMR technologií

Elektromagnetické pole

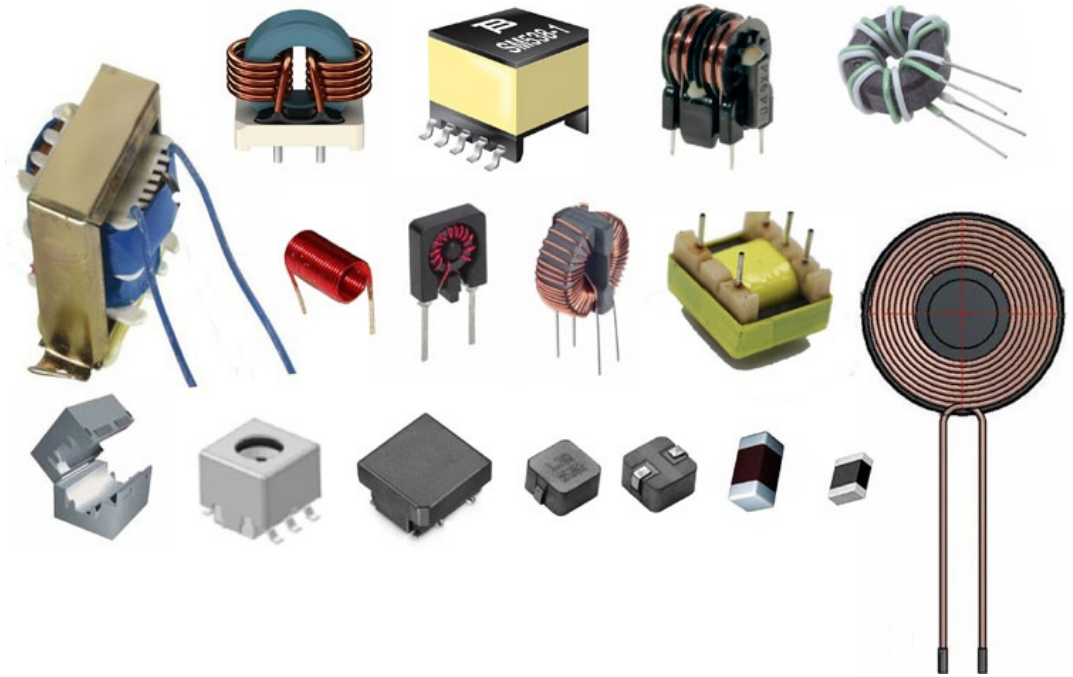


Zdroj obrázku: https://media.geeksforgeeks.org/wp-content/uploads/20251211112403202726/magnetic_field.webp

Kondenzátor? Cívka?



Zdroj: jlcpcb.com



Zdroj: rfcafe.com

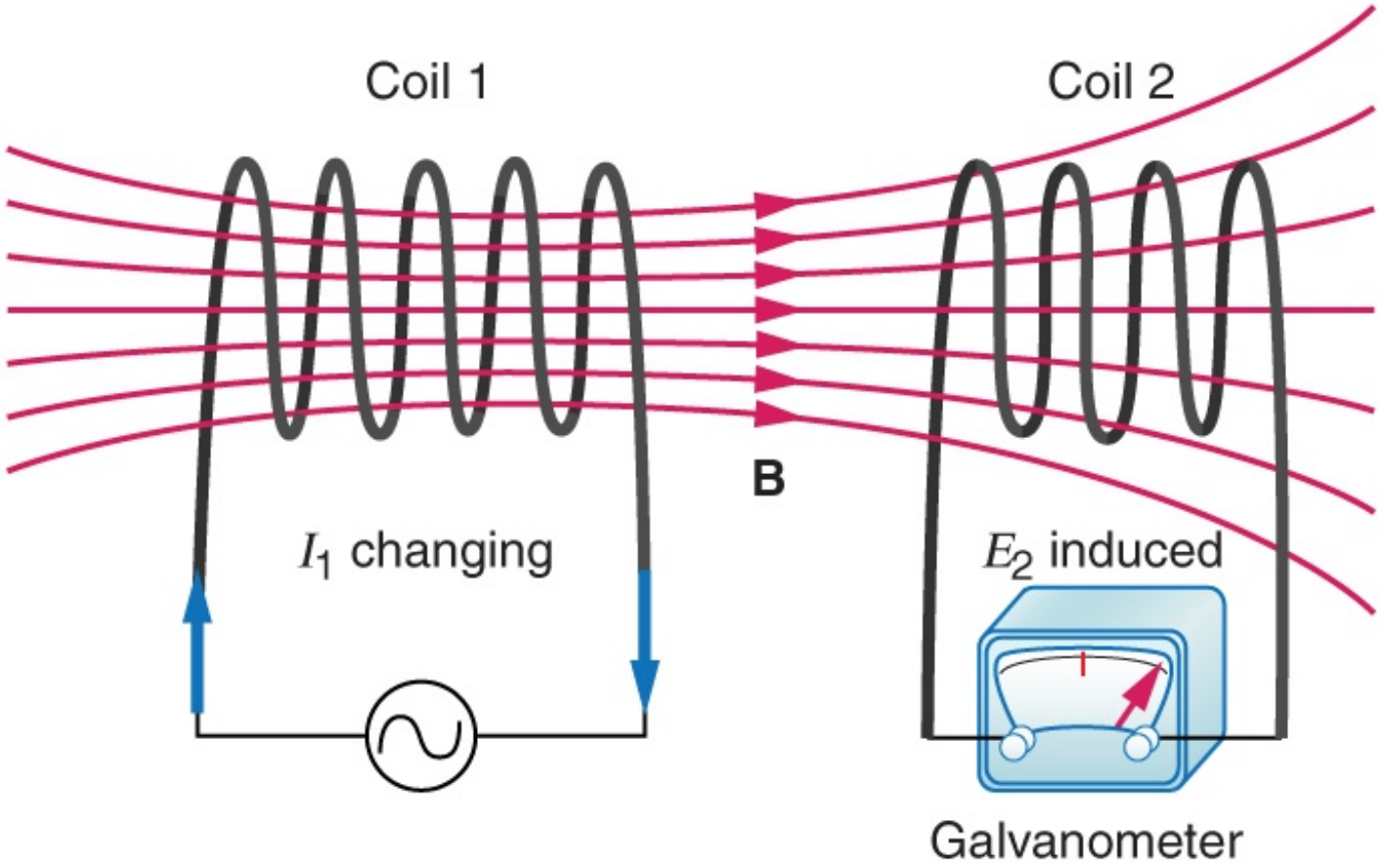
Kondenzátor

Zásobárna **elektrického** pole (akumuluje elektrický náboj)

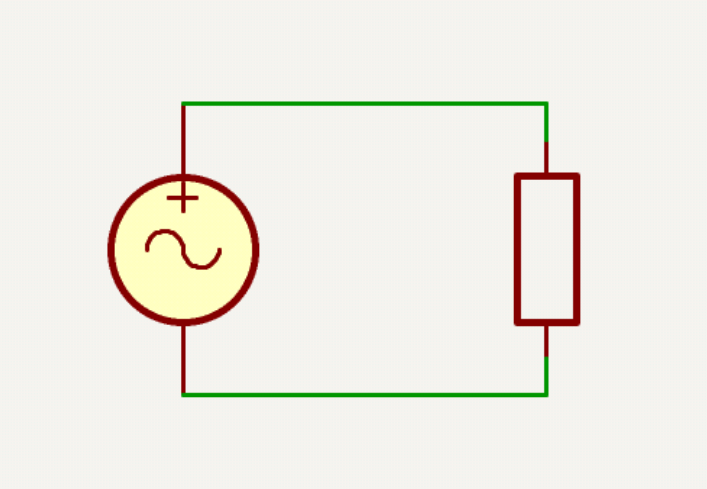
Cívka

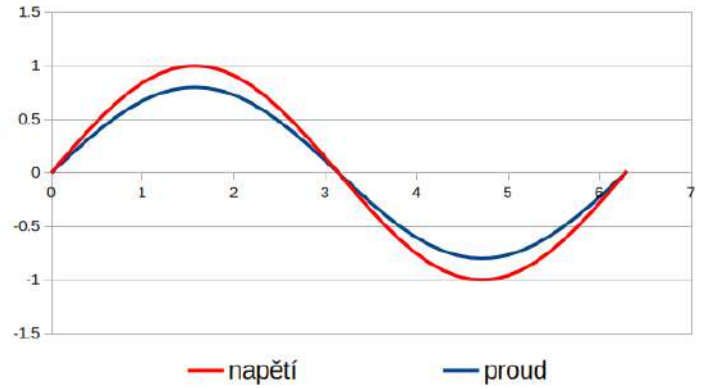
Zásobárna **magnetického** pole ("setrvačník" elektrického proudu)

Elektromagnetická indukce

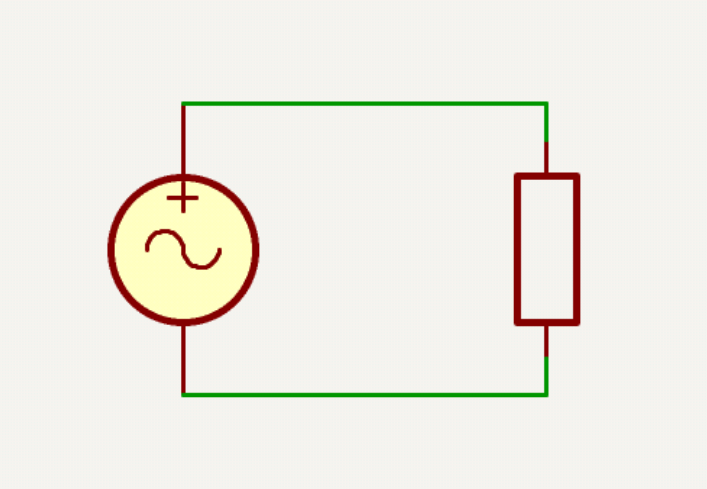


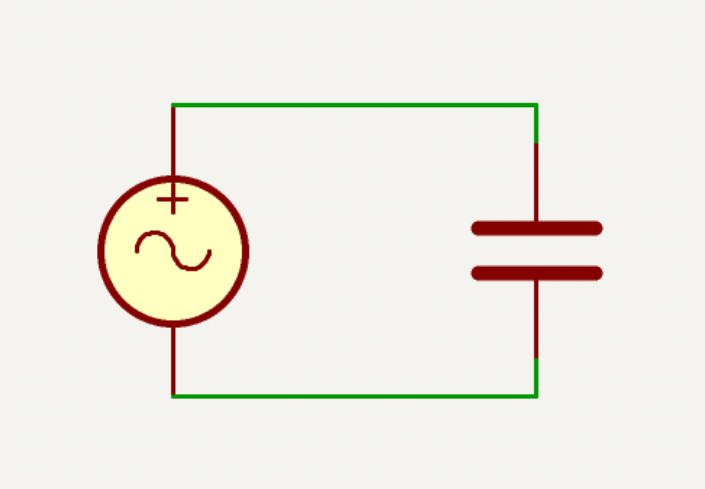
Zdroj obrázku: openbooks.lib.msu.edu

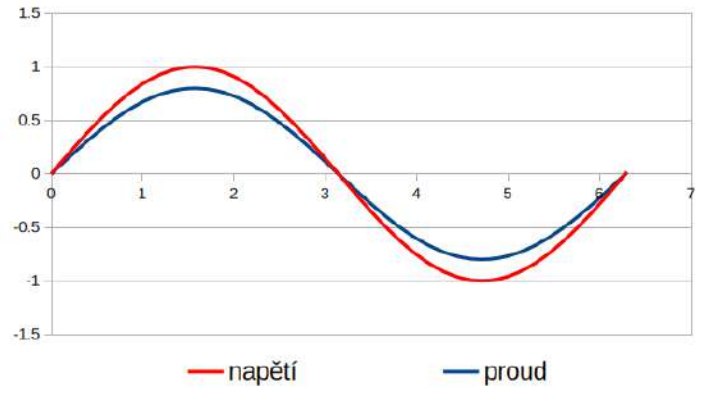


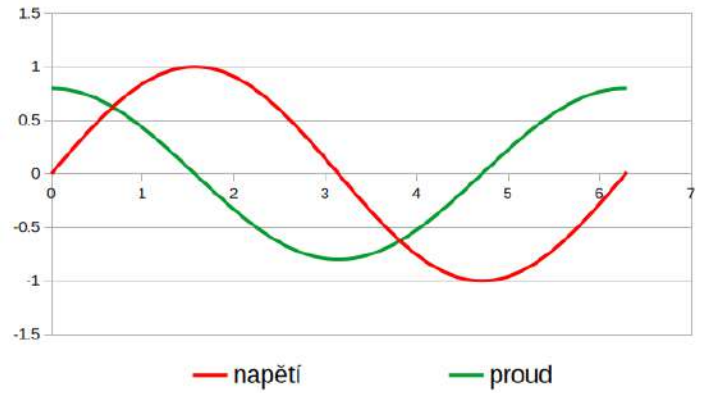


Bez fázového posunu



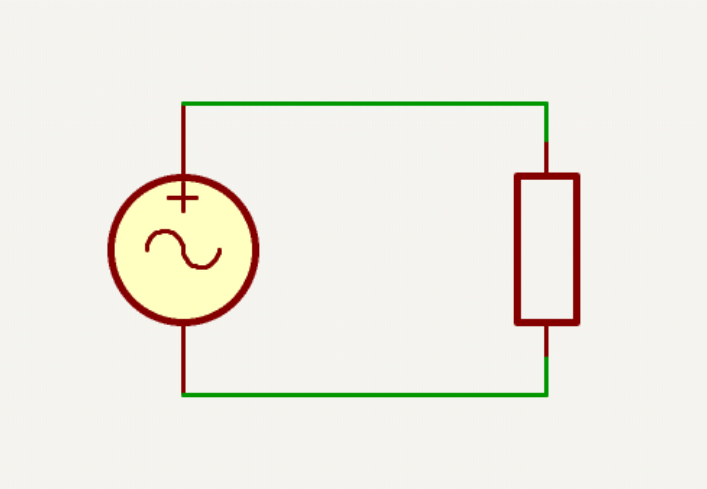


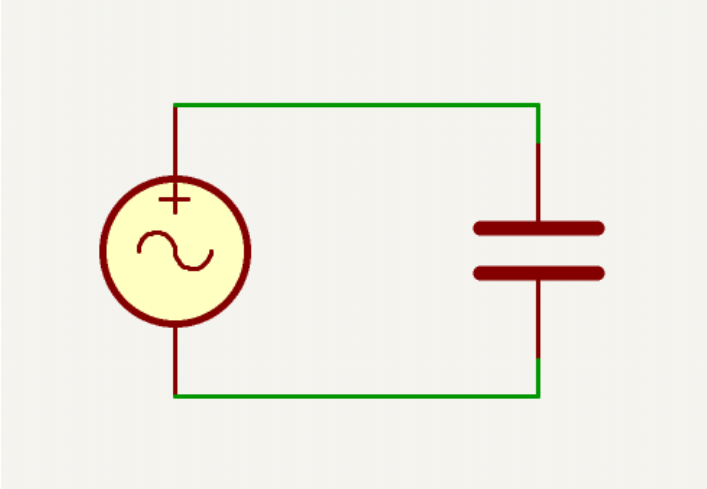


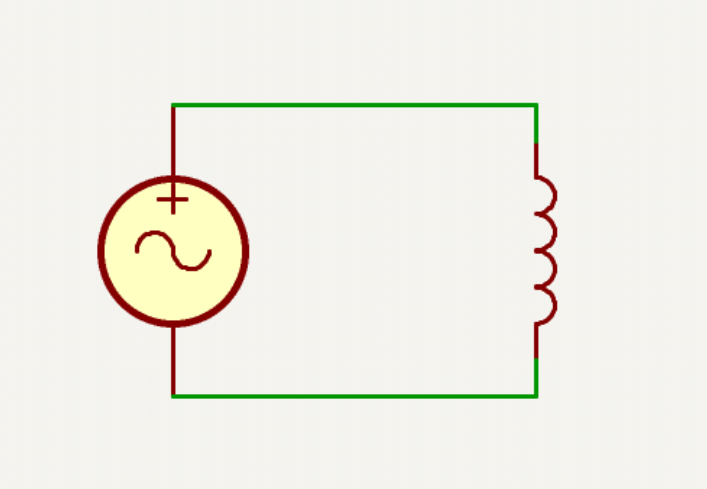


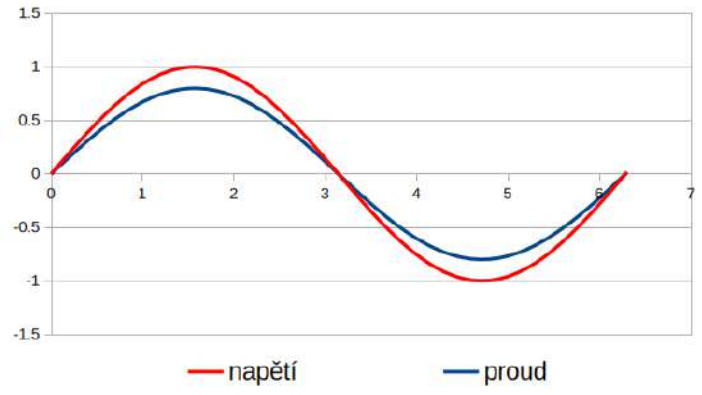
Bez fázového posunu

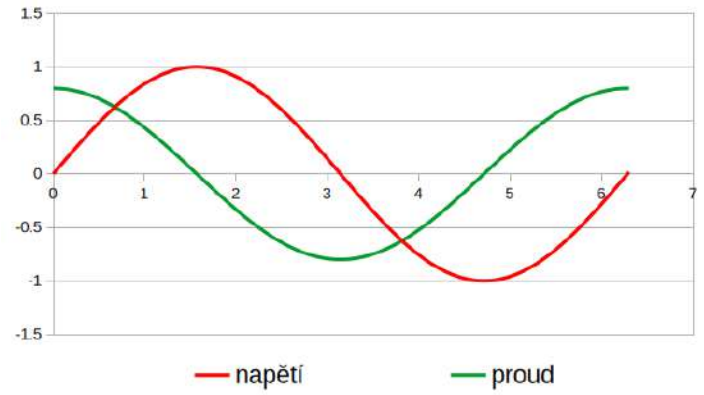
Fázový posun $+90^\circ$ $(+\frac{\pi}{2}rad)$

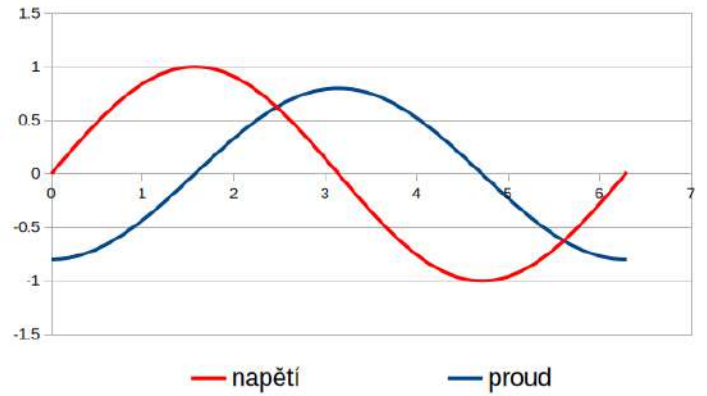








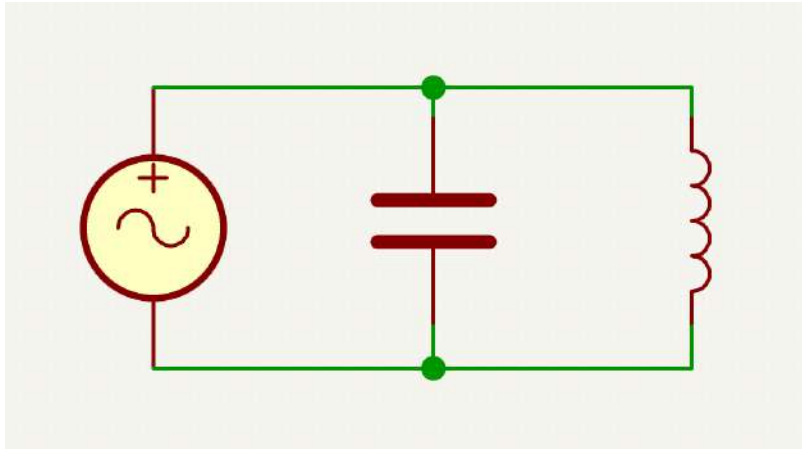


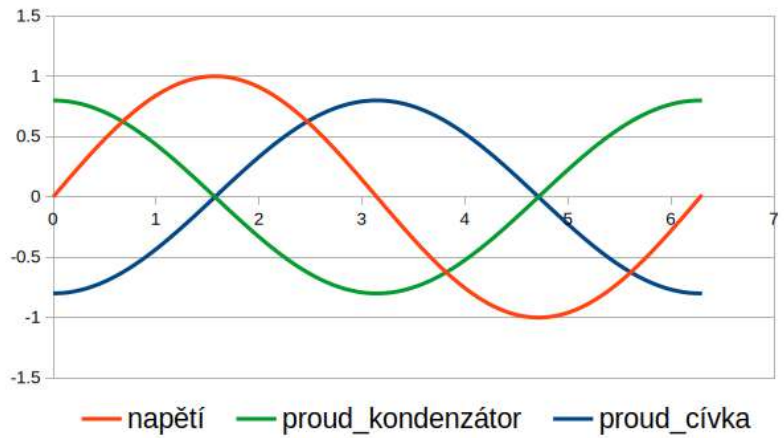


Bez fázového posunu

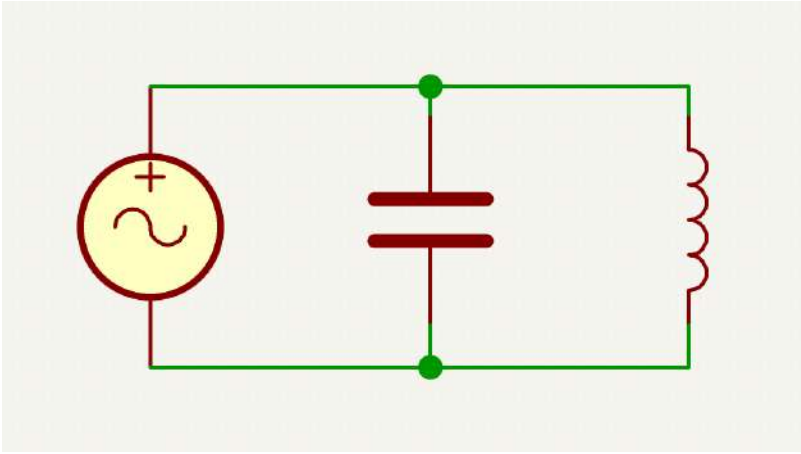
Fázový posun $+90^\circ$ $(+\frac{\pi}{2}rad)$

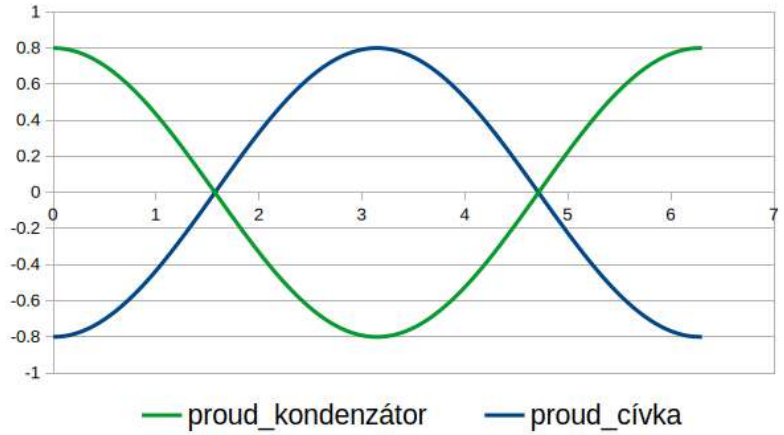
Fázový posun -90° $(-\frac{\pi}{2}rad)$



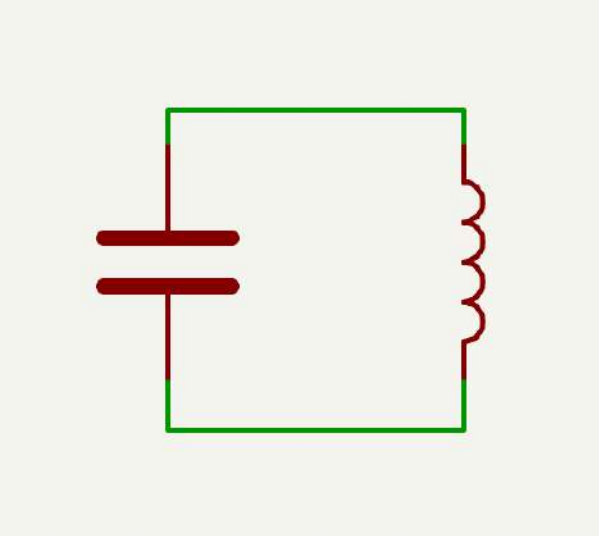

1.5
1
0.5
0
-0.5
-1
-1.5
0
1
2
3
4
5
6
7
napětí
proud_kondenzátor
proud_cívka

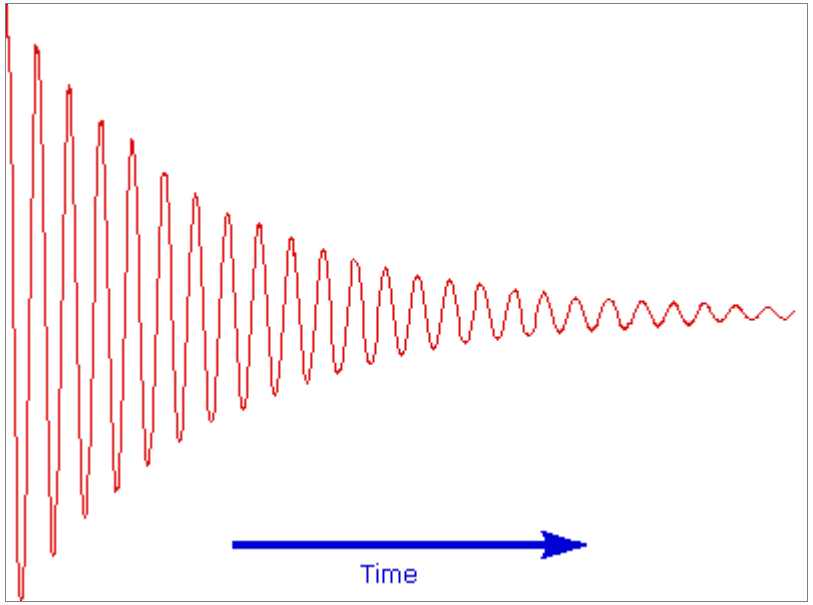
EMR = elektromagnetická rezonance





EMR = elektromagnetická rezonance





Zdroj obrázku: chem.libretexts.org

Reaktance

= odpor závislý na frekvenci

$$X_C = \frac{1}{2\pi f C}$$

kde:

X_C = Reaktance kondenzátoru v Ω
C = Kapacita kondenzátoru ve F

$$X_L = 2\pi f L$$

kde:

X_L = Reaktance cívky v Ω
L = Indukčnost cívky v H

Rezonanční frekvence

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

... kde:

f_r = **rezonanční** frekvence v Hz

C = kapacita kondenzátoru ve F

L = indukčnost cívky v H

Reaktance

= odpor závislý na frekvenci

$$X_C = \frac{1}{2\pi f C}$$

kde:

X_C = Reaktance kondenzátoru v Ω

C = Kapacita kondenzátoru ve F

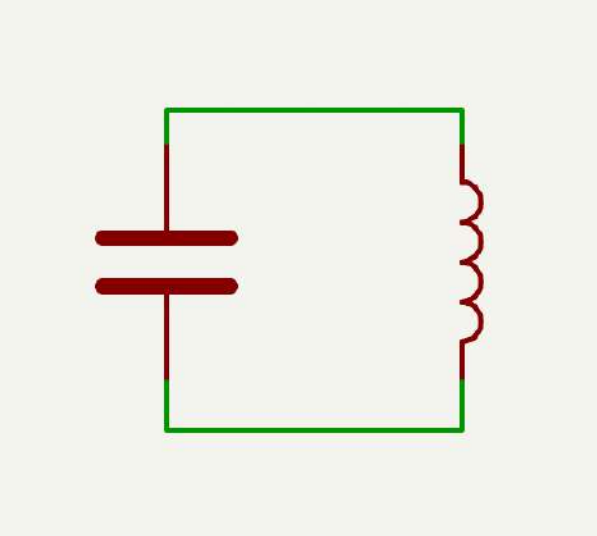
$$X_L = 2\pi f L$$

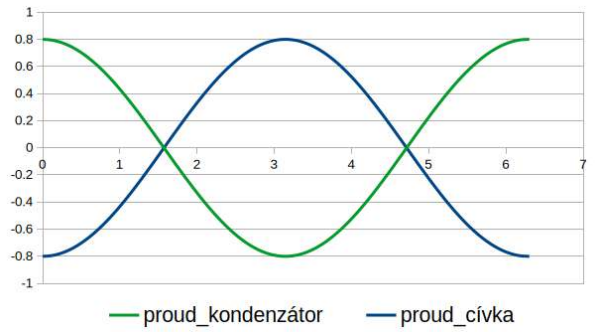
kde:

X_L = Reaktance cívky v Ω

L = Indukčnost cívky v H

Rezonanční frekvence





$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

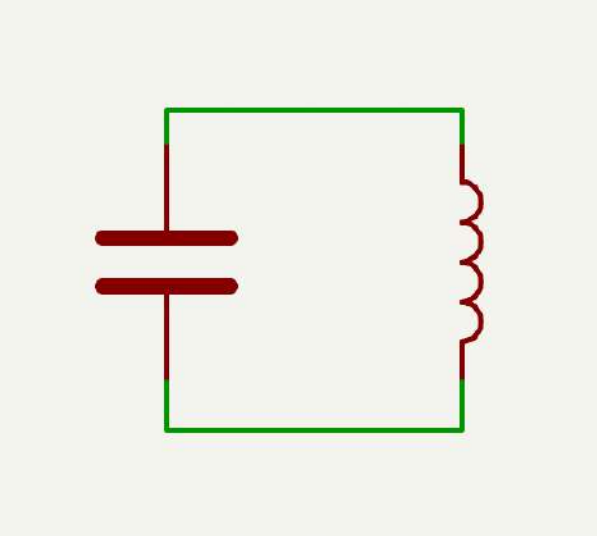
... kde:

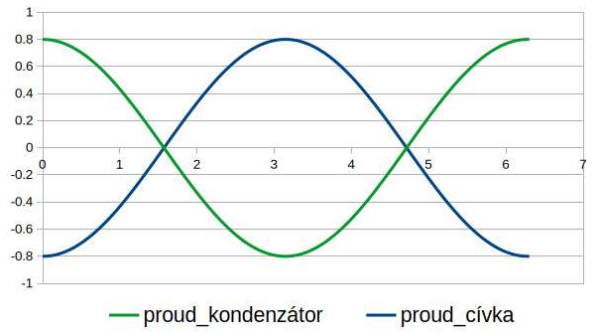
f_r = **rezonanční** frekvence v Hz

C = kapacita kondenzátoru ve F

L = indukčnost cívky v H

Rezonanční frekvence





$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

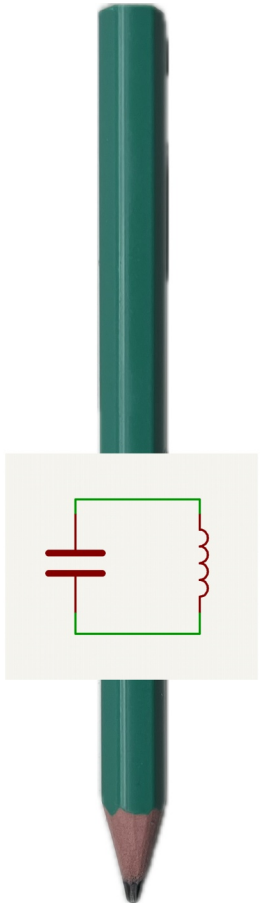
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

... kde:

f_r = **rezonanční** frekvence v Hz

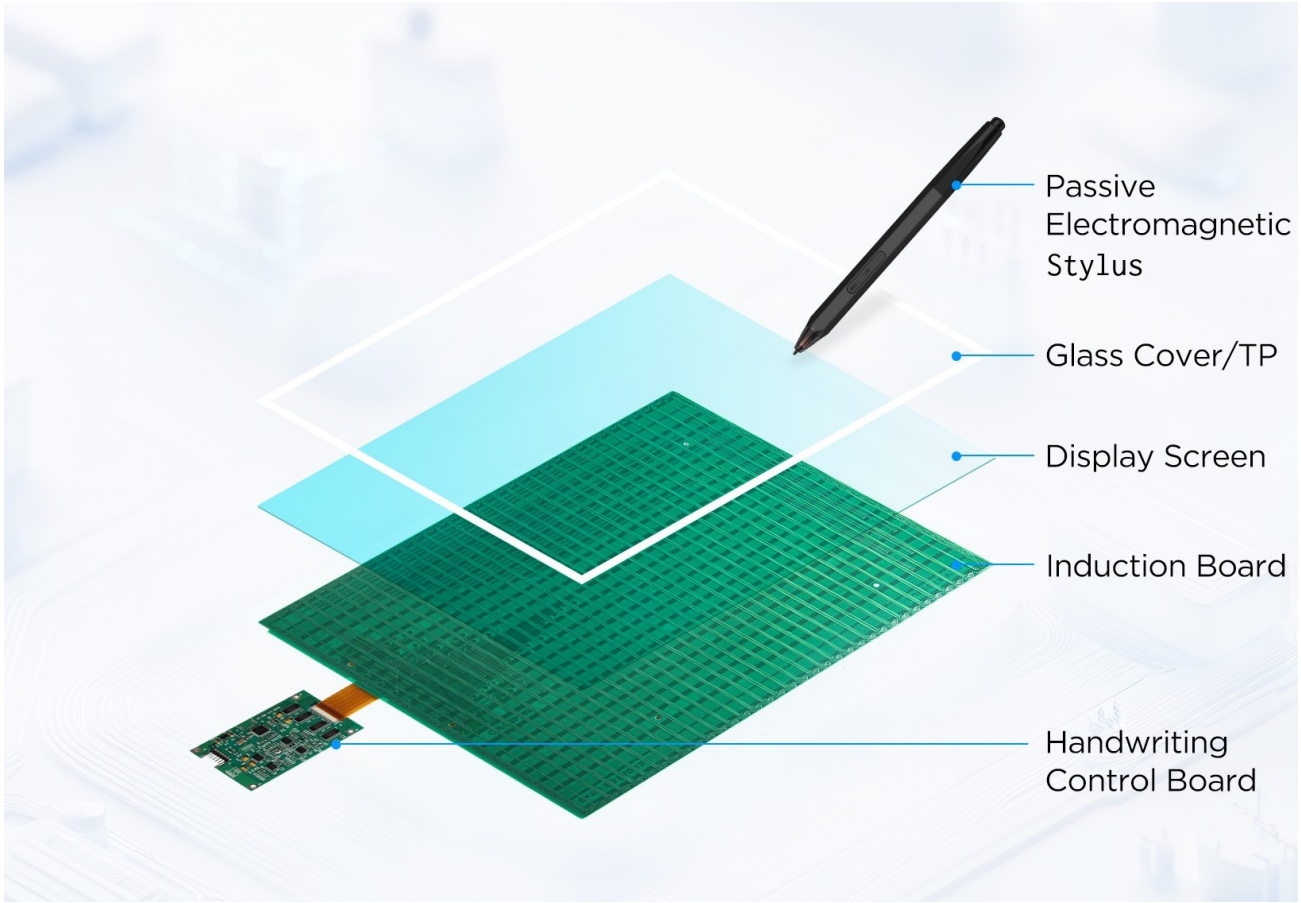
C = kapacita kondenzátoru ve F

L = indukčnost cívky v H



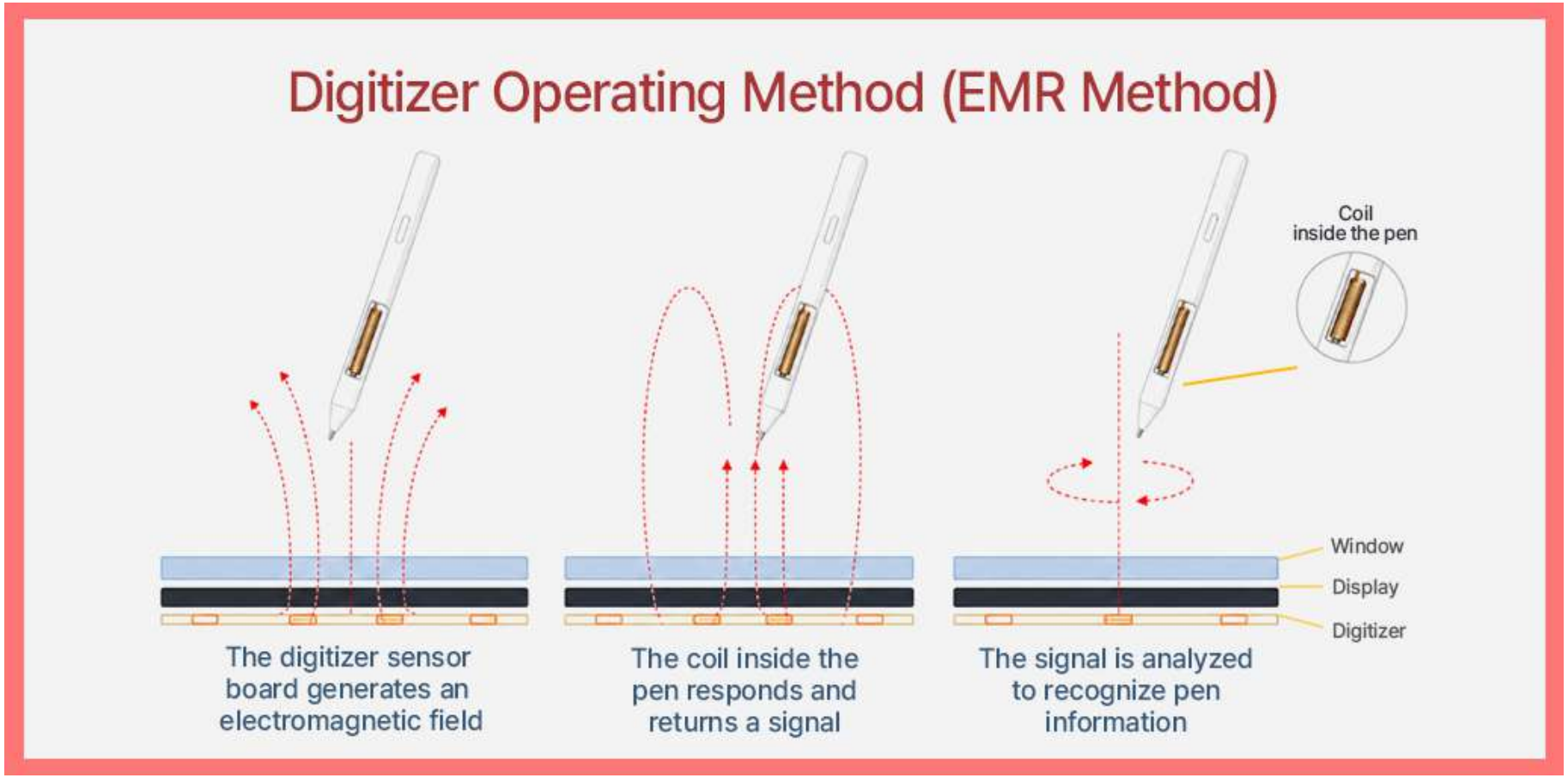
pasivní EMR stylus

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



Zdroj obrázku: https://business.hanvonugee.com/uploads/20250418/481d39d82a8dbc8f6db8d70a41a88daf.jpg

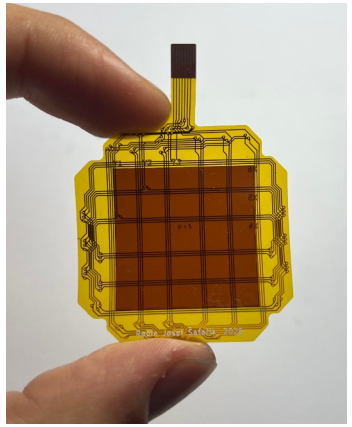
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



Zdroj obrázku: https://business.hanvonugee.com/uploads/20250418/481d39d82a8dbc8f6db8d70a41a88daf.jpg

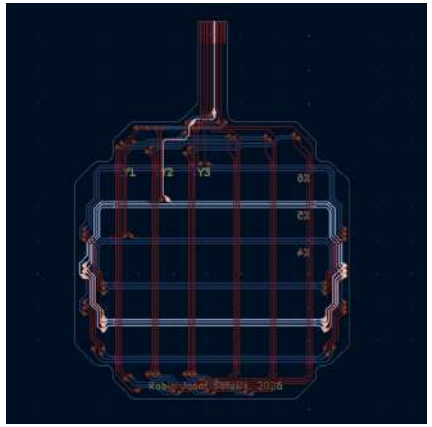
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Snímání polohy stylusu

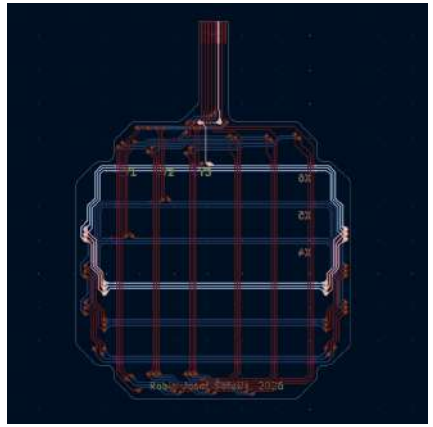




Horizontální 1



Horizontální 2



Horizontální 3



Vertikální 1



Vertikální 2



Vertikální 3

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

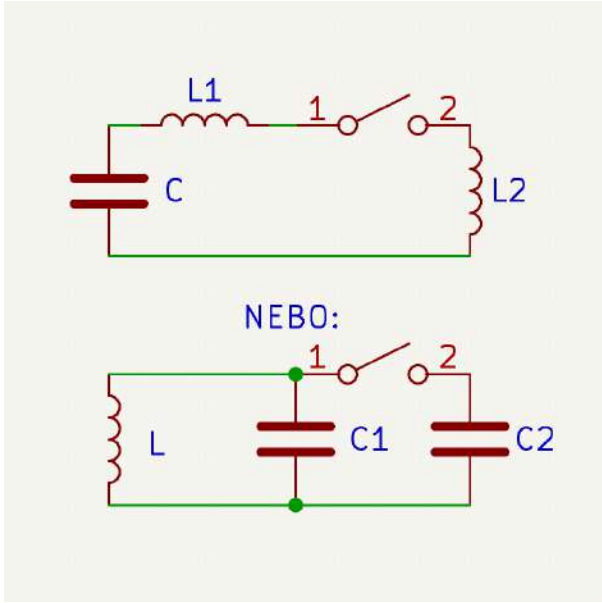
Jak funguje přítlak a stisk tlačítek



Zdroj obrázku: imimg.com



Zdroj obrázku: media-amazon.com



Přítlak - **variabilní** cívka / kondenzátor

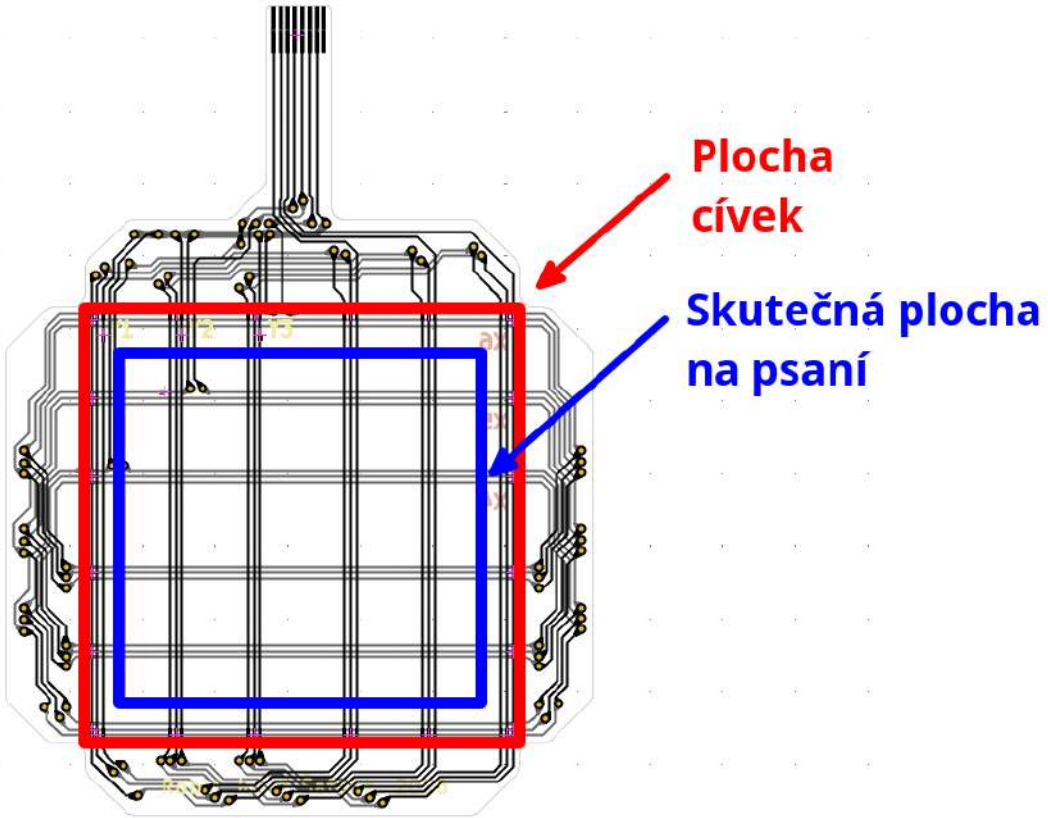
Tlačítka - posun f_r

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Technické výzvy při návrhu EMR digitizéru

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

1) Špatné snímání na okrajích a v rozích mřížky



$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

2) Špatná dokumentace

- Technologie dlouho patentována společností Wacom (většina patentů už vypršela!)

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

2) Špatná dokumentace

- Technologie dlouho patentována společností Wacom (většina patentů už vypršela!)

Prezentace neslouží k propagaci konkrétních značek.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

2) Špatná dokumentace

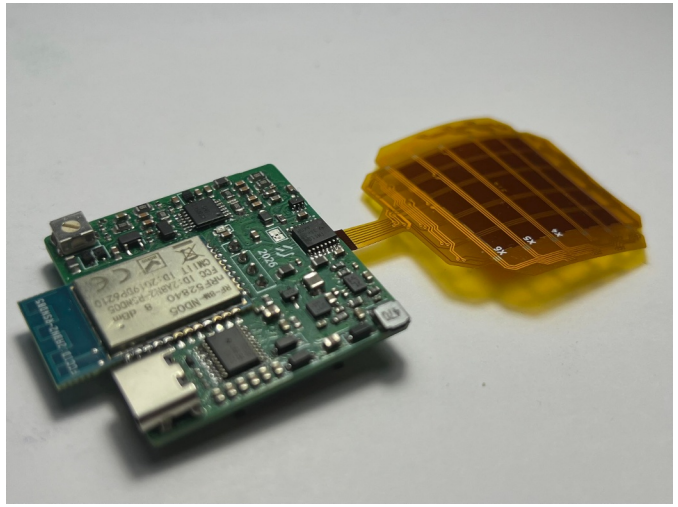
- Technologie dlouho patentována společností Wacom
  (většina patentů už vypršela!)
- Neexistuje volně prodejný IC řešící analogovou část (zesílení, filtraci…)

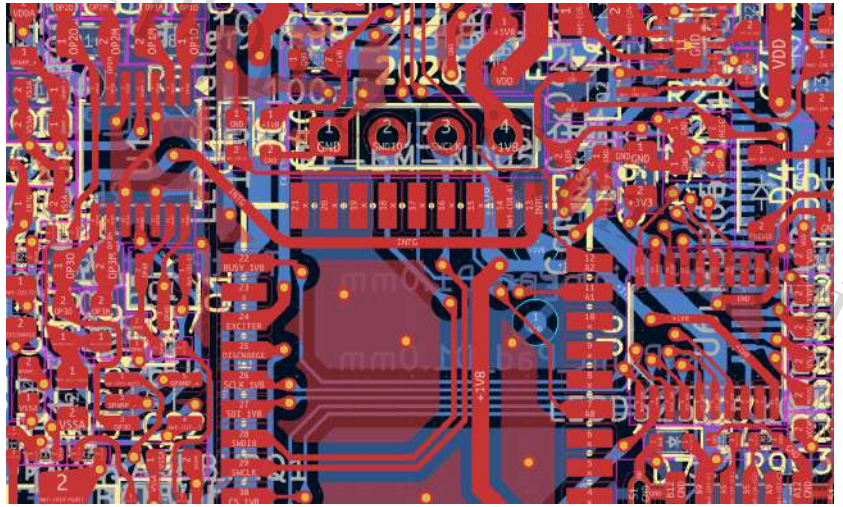
Prezentace neslouží k propagaci konkrétních značek.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

2) Špatná dokumentace

- Technologie dlouho patentována společností Wacom
  (většina patentů už vypršela!)
- Neexistuje volně prodejný IC řešící analogovou část (zesílení, filtraci…)
- Člověk si musí obvod navrhnout sám



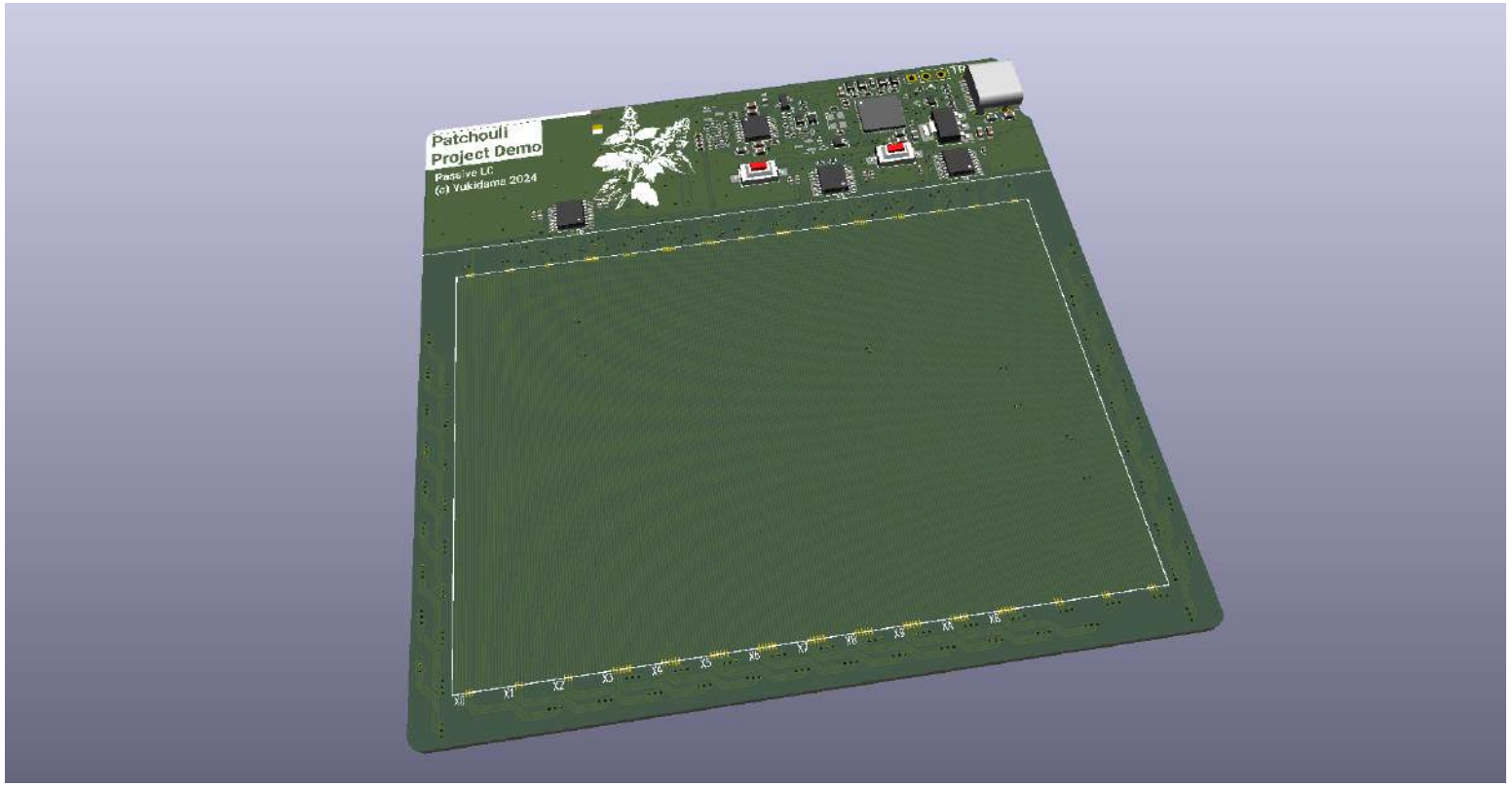


$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Prezentace neslouží k prodeji. Použité obrázky mohou být chráněny autorskými značek.

Jak začít s návrhem vlastního EMR digitizéru?

- Doporučuji open-source projekt "**Patchouli**" detailně popisující technologii EMR
  Gitlab: https://gitlab.com/yukidama/patchouli



Děkuji za pozornost!



kontakt@robinsafarik.cz