LAPORAN PRAKTIKUM
SISTEM INSTRUMENTASI ELEKTRONIKA
MODUL III

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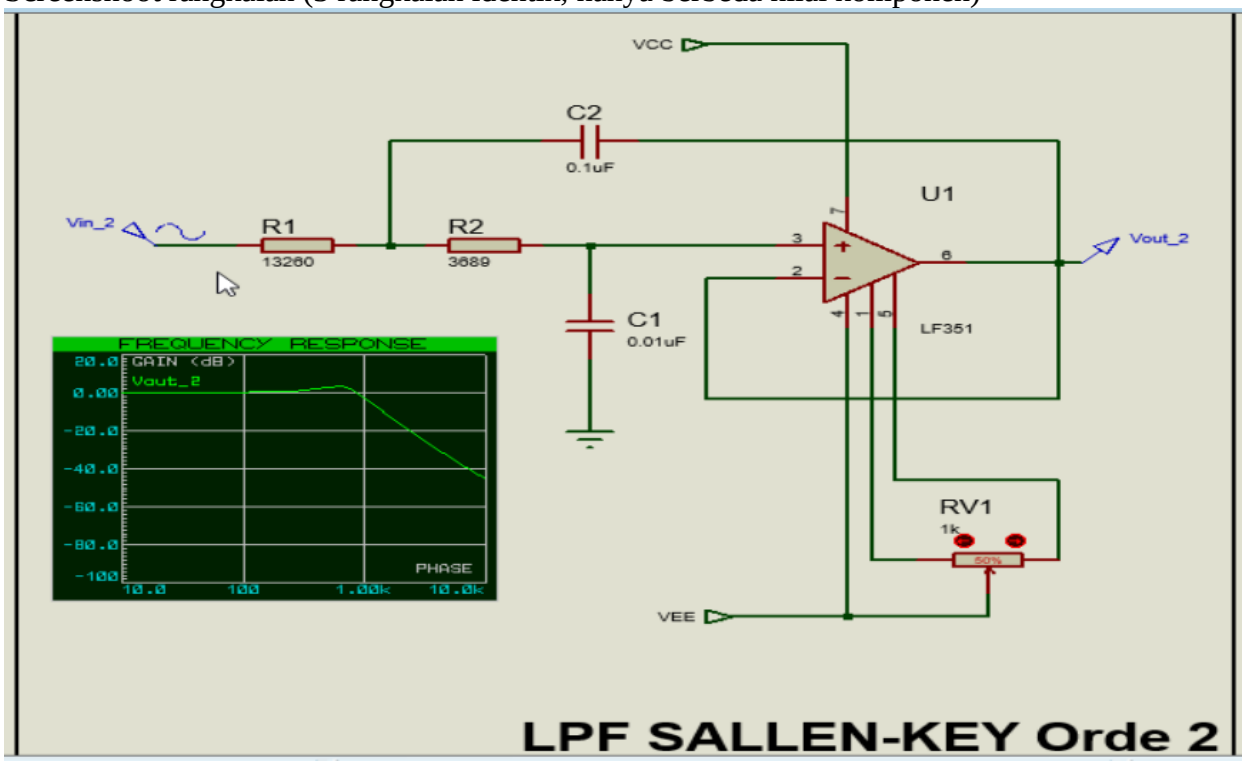
Hari & jam Prakt.: Rabu, 1 September 2021, 13.00

Dosen / Asisten: Lanny Augustine **Paraf:**

<u>Tugas awal (jawaban diletakkan di Lampiran II):</u>
Jika amplitudo input adalah 5Vpeak, hitunglah Amplitudo output pada Gain -3dB, -40dB, -60dB!

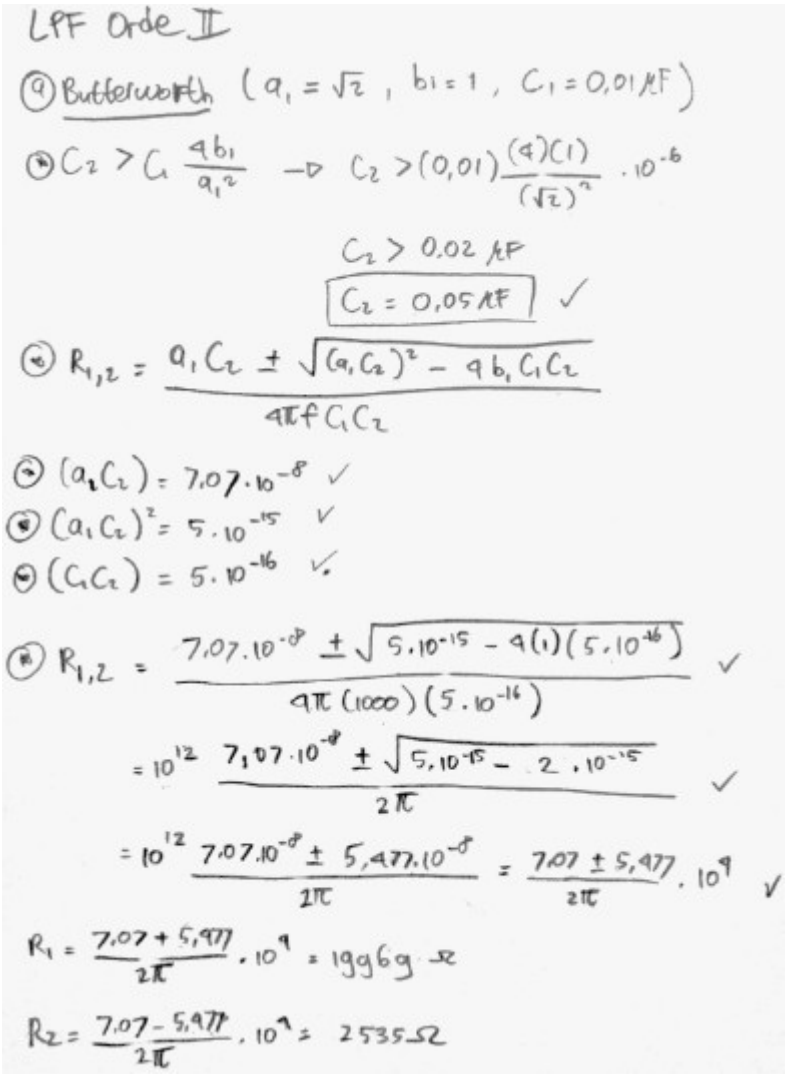
A. *Lowpass Filter* Orde 2

Screenshoot rangkaian (3 rangkaian identik, hanya berbeda nilai komponen)

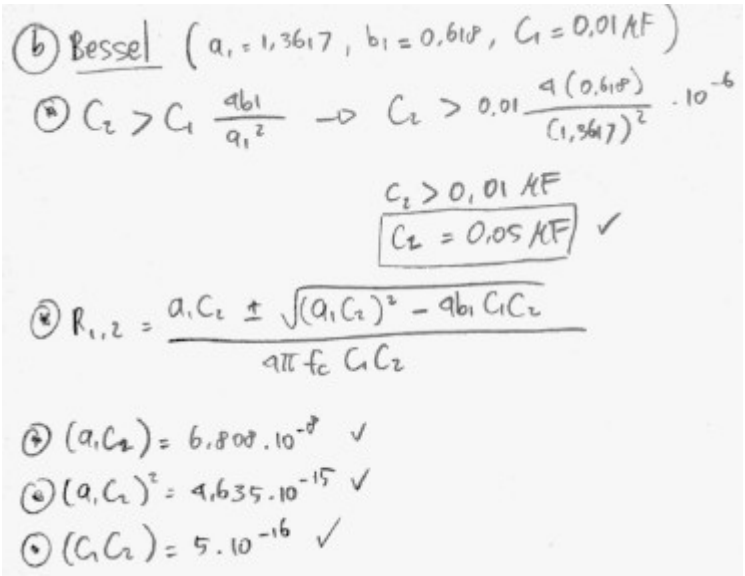


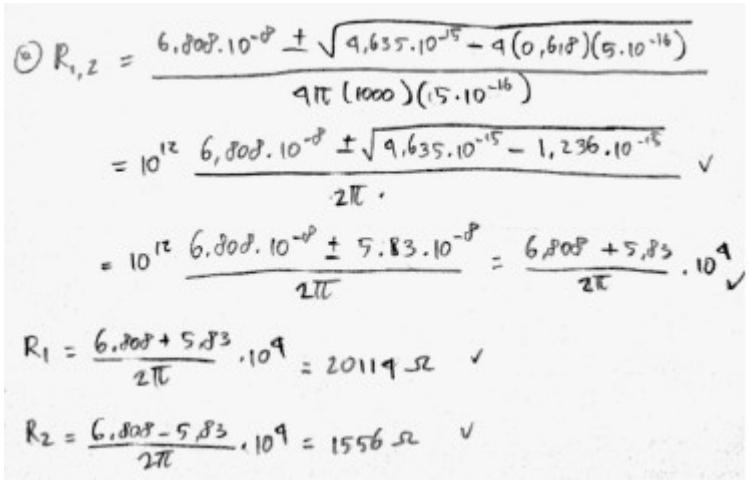
Perhitungan desain rangkaian

Butterworth

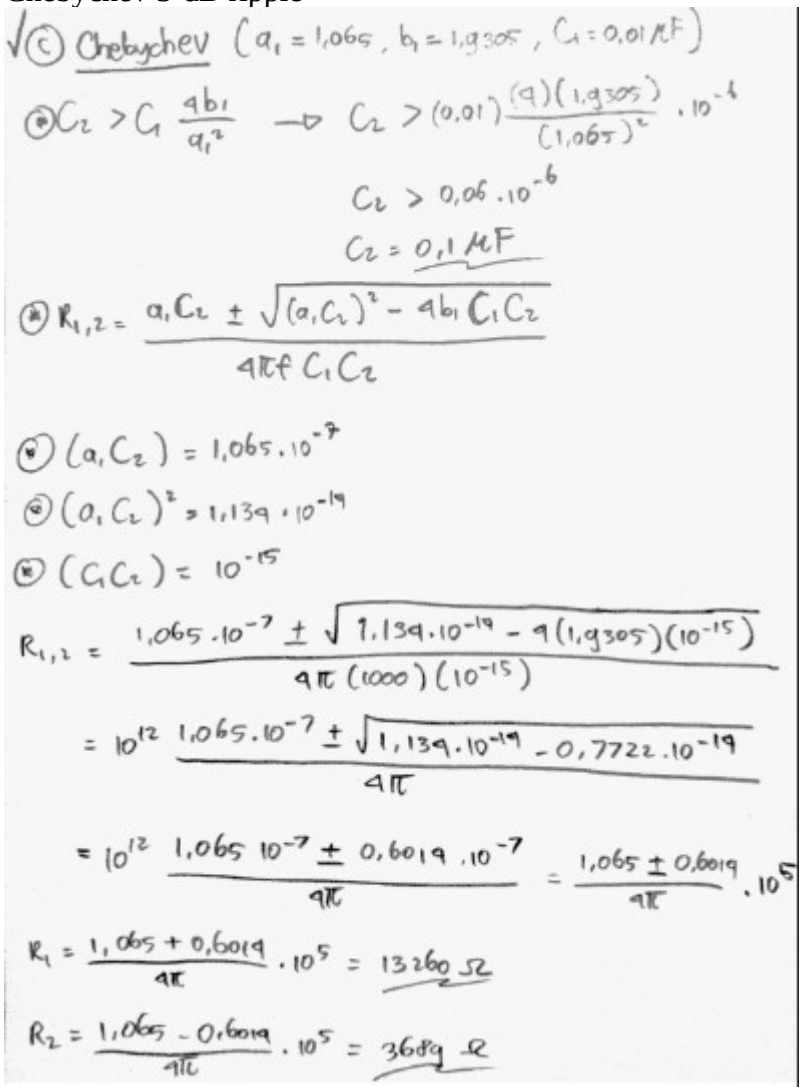


Bessel





Chebychev 3-dB ripple



Hasil percobaan:

Vcc = 9 volt; f_{cutoff} = 1000 Hz; C1 = 0,01μF

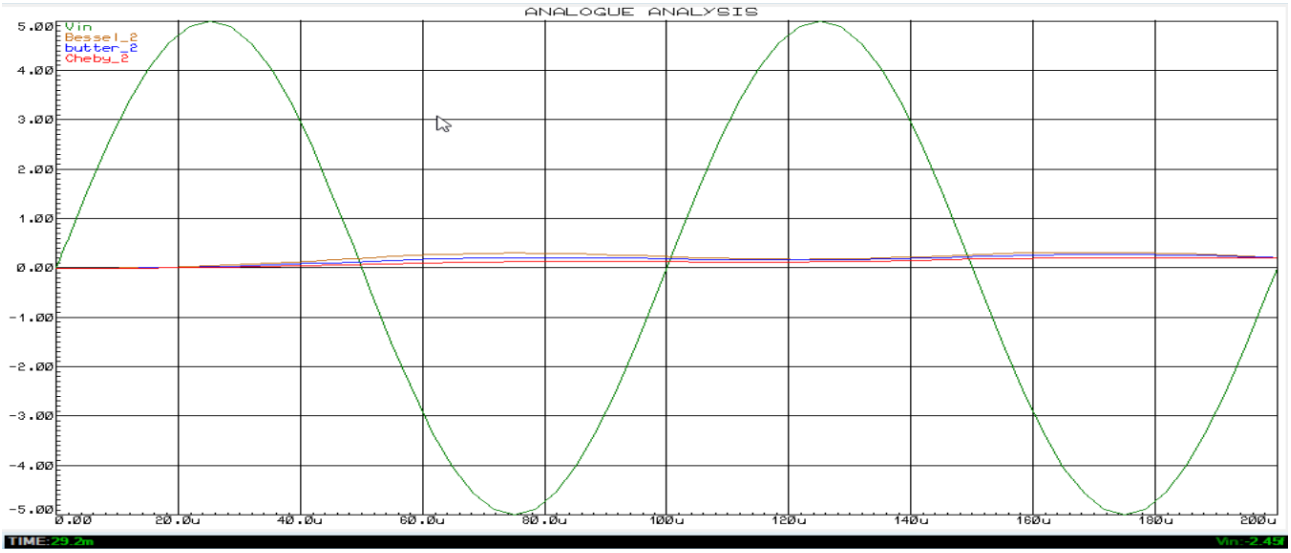
Tabel 3.1

Vin (Vpeak)	Fin (Hz)	Fout (Hz)	Vout (Vpeak)		
			Butterworth C_2= 0.05 uF R_1= 19969 Ω R_2= 2535 Ω	**Bessel** C_2= 0.05 uF R_1= 20114 Ω R_2= 1556 Ω	**Chebychev** C_2 = 0.1 uF R_1 = 13260 Ω R_2 = 3689 Ω
5 V	10	10	4.99	4.99	4.99
	100	100	4.99	4.99	4.99
	1000	1000	3.57	3.63	3.80
	10000	10000	0.0362	0.0728	0.0363

Catatan:

Hasil simulasi di Proteus saya export menjadi file Excel, lalu saya plot menggunakan Python, karena kualitas screenshot saya untuk grafik di Proteus kurang baik. Untuk kedepannya, semua hasil simulasi akan saya export terlebih dahulu.

Berikut contoh salah satu hasil screenshot langsung dari Proteus:



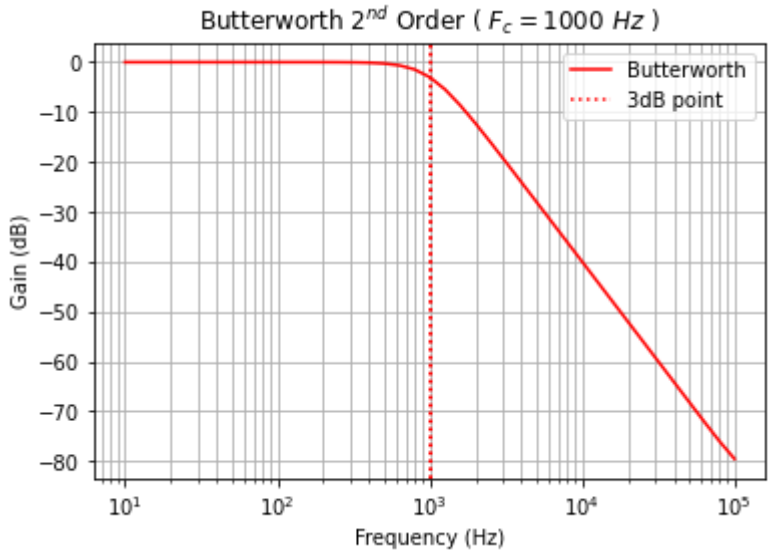
Untuk link dokumen source code Python Jupyter Notebook (bisa di download kemudian di view melalui browser seperti Google Chrome / Mozilla Firefox) :

https://drive.google.com/file/d/13Cxduiri3ffKQppW4PeuKRJWjKuAm2bw/view?usp=sharing

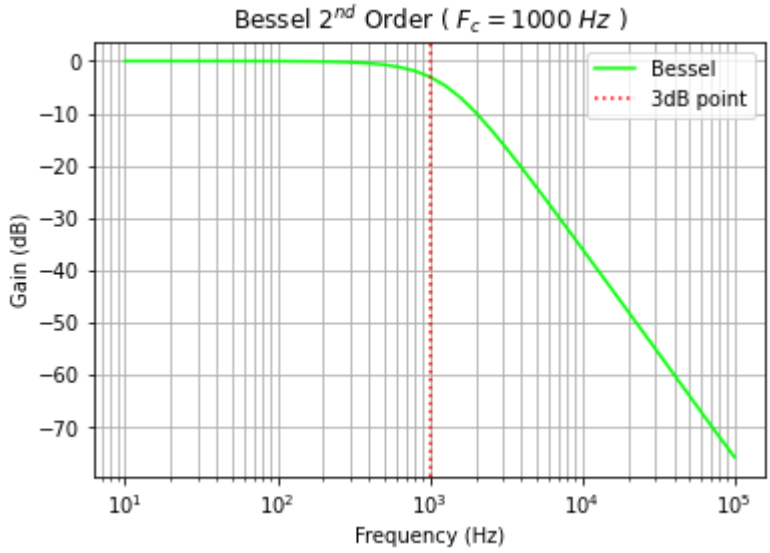
Atau live view melalui repository github :

https://github.com/yeyee2901/PRAK-SIE/blob/main/Modul%203/Notebook_Graphs.ipynb

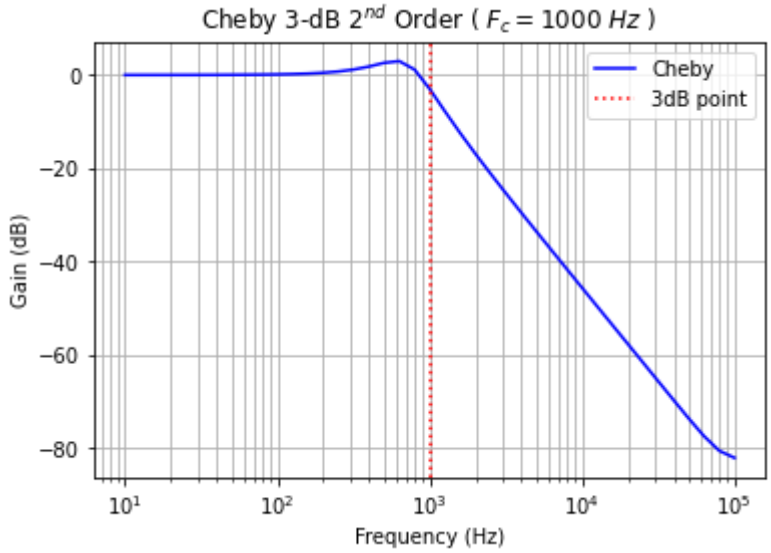
- Grafik respon frekuensi terhadap gain dalam skala logaritmik (diagram Bode) LPF orde 2:
  Butterworth



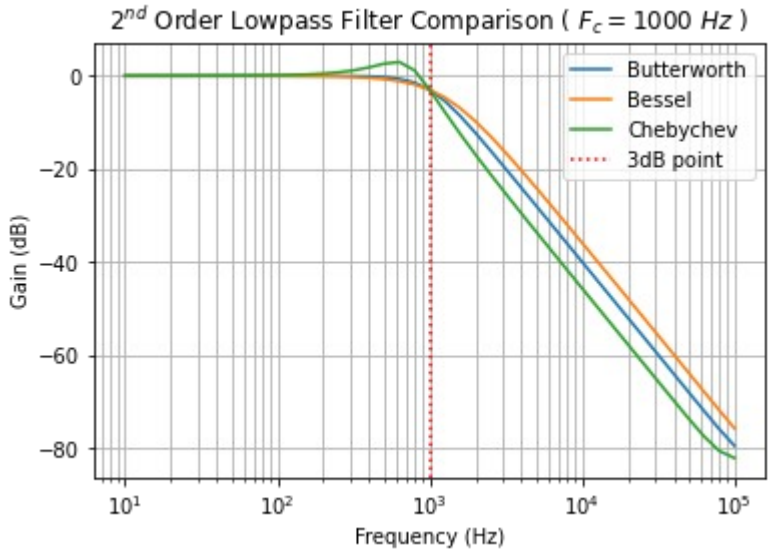
Bessel



Cheby 3-dB



Perbandingan 3 Filter



- Puncak *ripple* LPF Chebychev pada frekuensi input = **630.957344 Hz**, dengan Gain = **2.96946 dB**, maka amplitudo output LPF:

$$Vout = 10^{\frac{Gain(dB)}{20}} \; x \; 5V = 10^{\frac{2.96946}{20}} \; x \; 5V = 7.037898583V$$

Hasil dari Python:

Ripple maksimum memiliki magnitude (dB):

```
In [39]: LPF_orde2_freq["Cheby_2"].max()
Out[39]: 2.96946
```

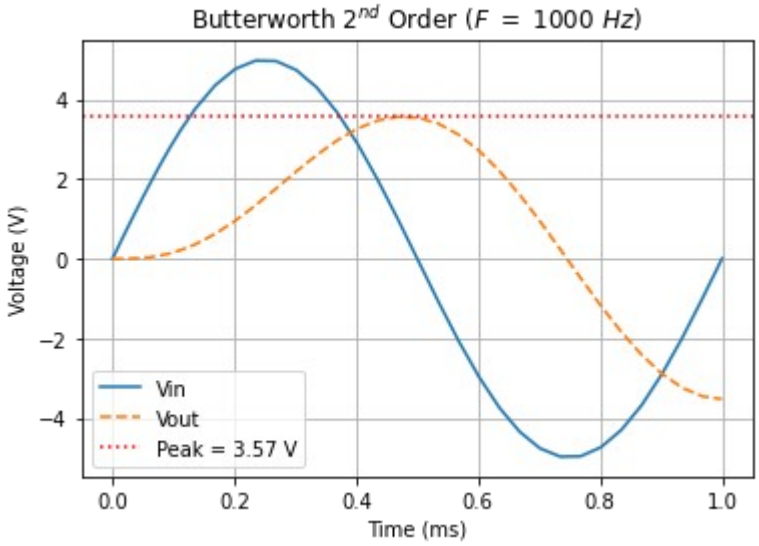
Puncak tersebut terdapat pada frekuensi (Hz):

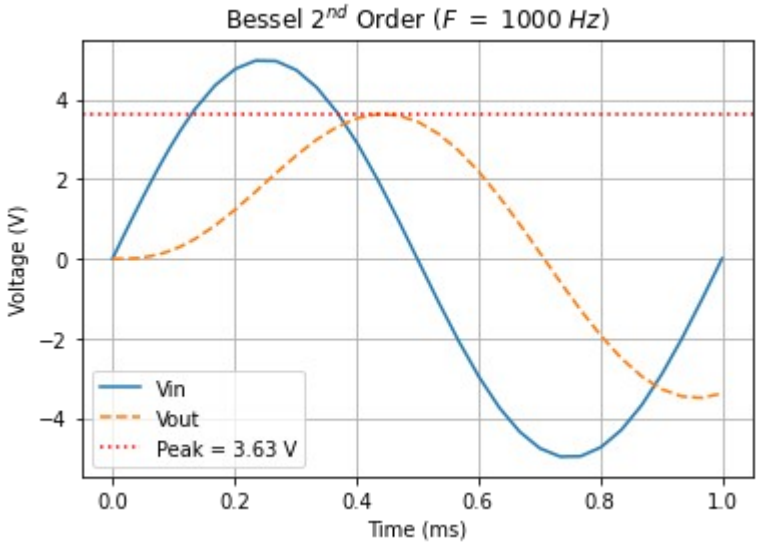
```
In [46]: LPF_orde2_freq[
             LPF_orde2_freq["Cheby_2"] == LPF_orde2_freq["Cheby_2"].max()
         ][["FREQ", "Cheby_2"]]
```

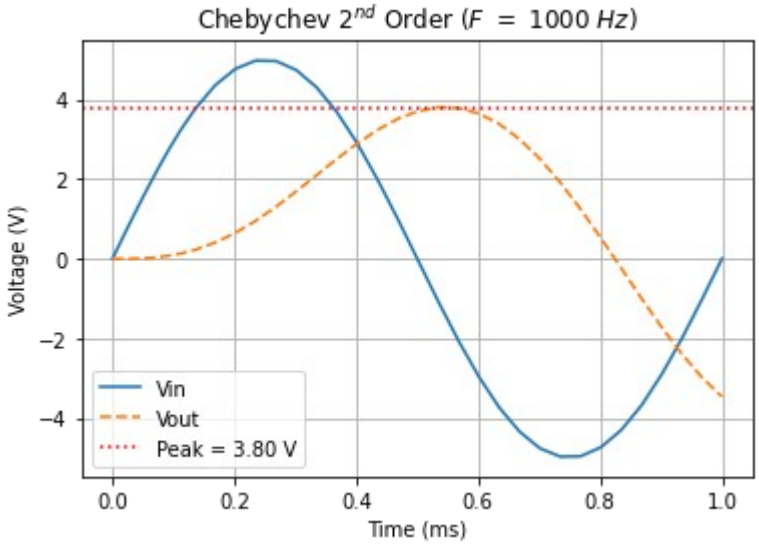
Out[46]:

	FREQ	Cheby_2
18	630.957344	2.96946

- Gambarkan bentuk gelombang input dan output (time domain) LPF saat frekuensi cutoff :

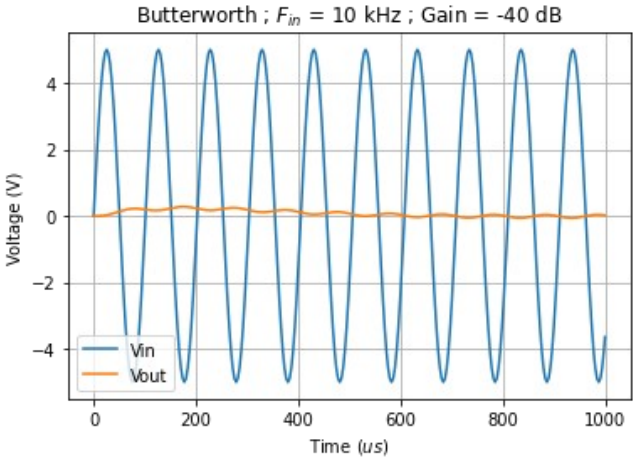


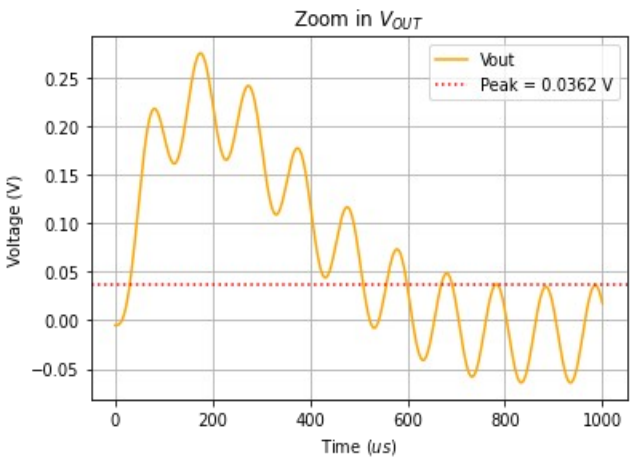




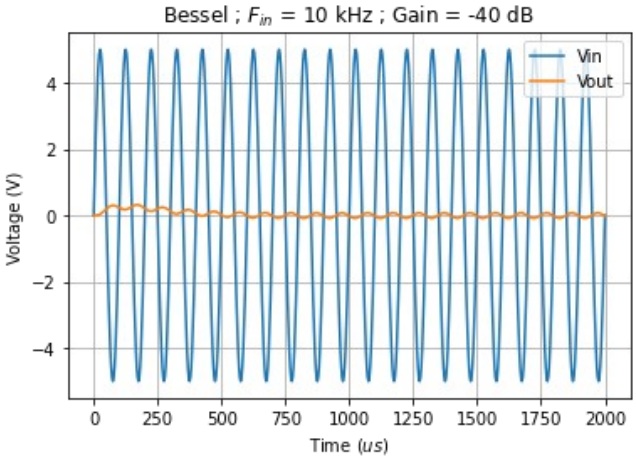
- Gambarkan bentuk gelombang input dan output (time domain) LPF saat Gain = -40dB:

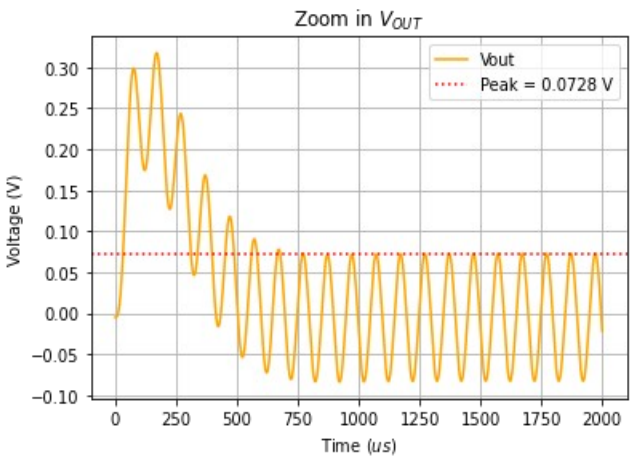
Butterworth



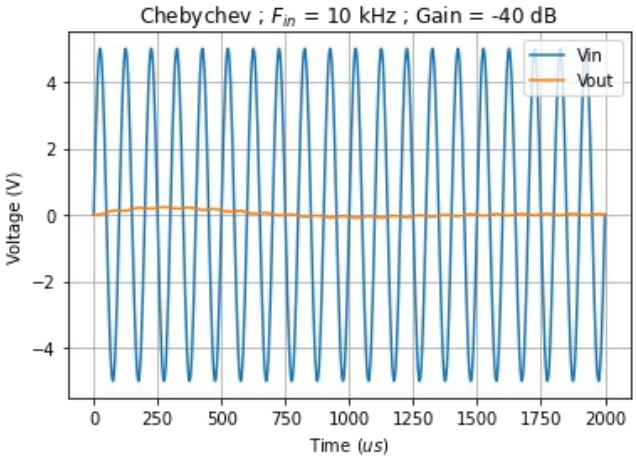


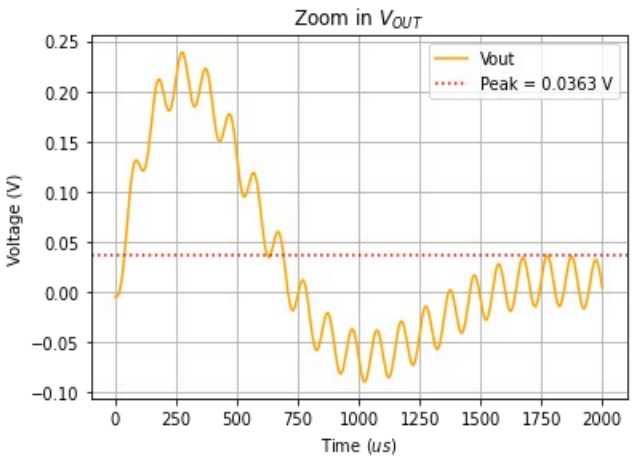
Bessel





Chebychev





Pembuktian perhitungan:

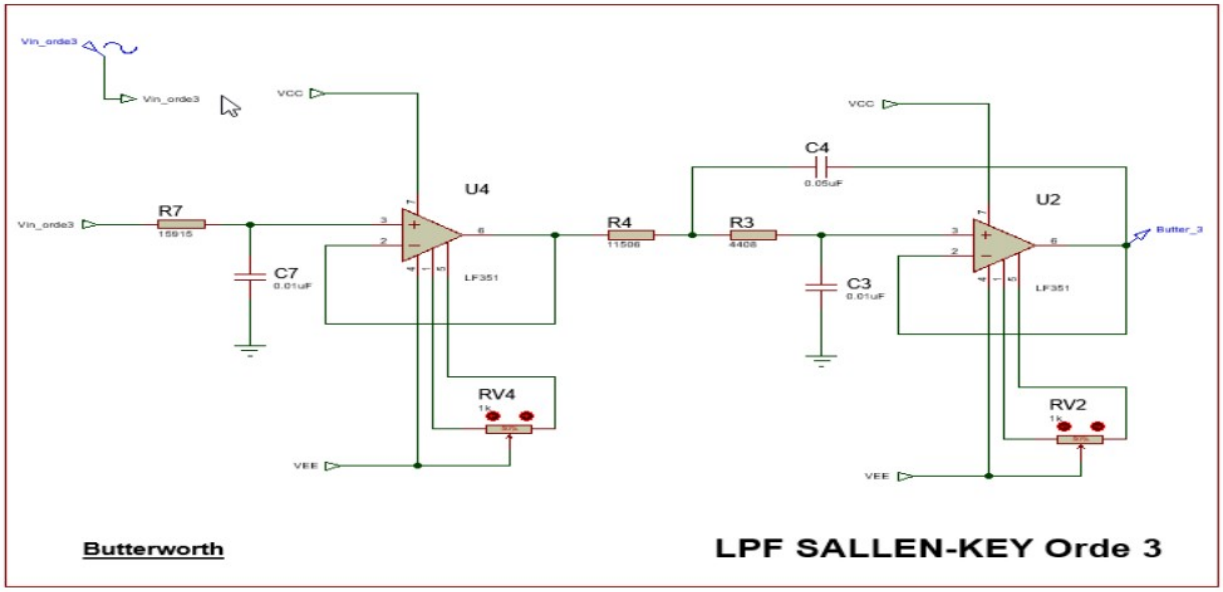
$$Gain(-40\,dB) = 0.01$$

$$Vout_{Peak} = 5\,x\,0.01 = 0.05V$$

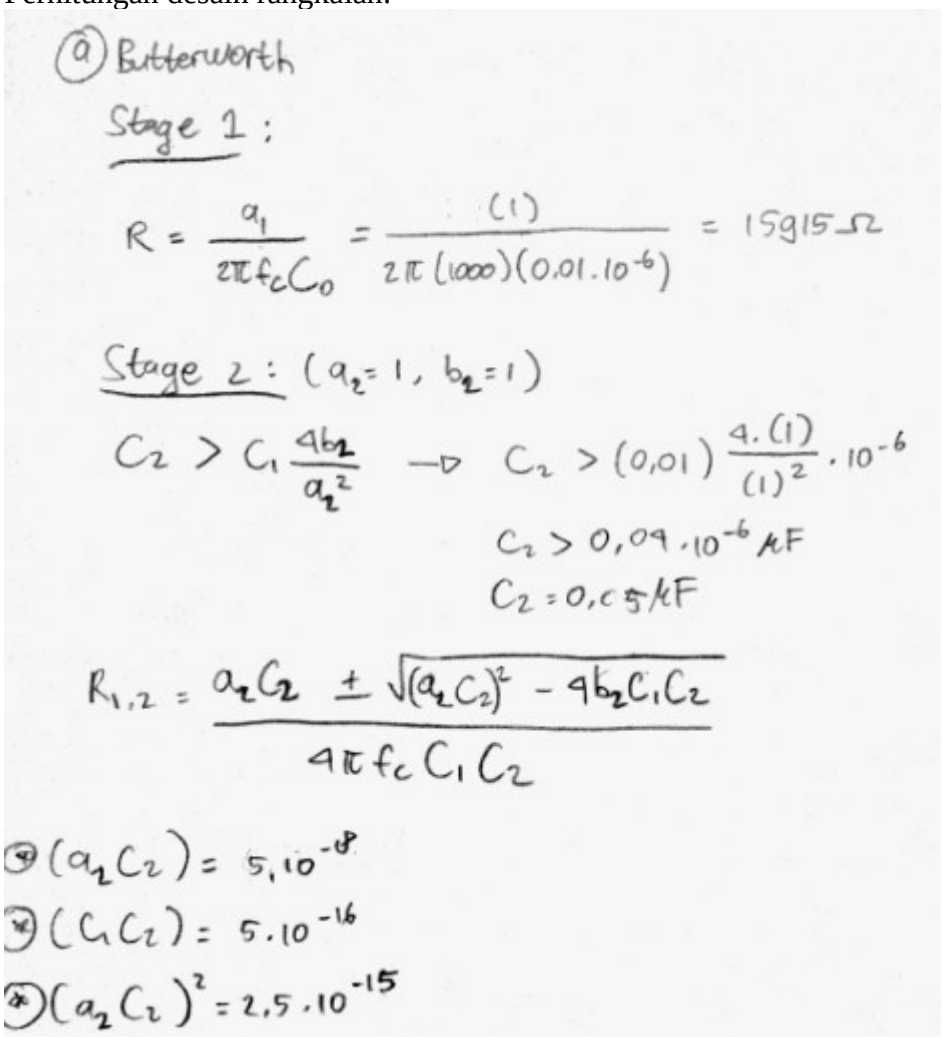
Penyebab dari ketidakcocokan tersebut adalah kemungkinan besar adalah karena dari hasil perhitungan resistor & kapasitor, saya memotong nilai desimal-nya.

B. *Lowpass Filter* Orde 3

Screenshoot rangkaian (rangkaian sama, hanya berbeda nilai komponen)



Perhitungan desain rangkaian:



$$R_{1,2} = \frac{5.10^{-8} \pm \sqrt{2,5.10^{-15} - 4(1)(5.10^{-16})}}{4\pi(1000)(5.10^{-16})}$$

$$= 10^{12}\ \frac{5.10^{-8} \pm \sqrt{2,5.10^{-15} - 2.10^{-15}}}{2\pi}$$

$$= 10^{12}\ \frac{5.10^{-8} \pm 2,23.10^{-8}}{2\pi} = \frac{5 \pm 2,23}{2\pi}\ .10^{4}$$

$$R_1 = \frac{5 + 2,23}{2\pi}\ .10^{4} = 11506\ \Omega$$

$$R_2 = \frac{5 - 2,23}{2\pi}\ .10^{4} = 4408\ \Omega$$

⑥ Bessel

Stage 1 : $(a_1 = 0,756)$

$$R = \frac{a_1}{2\pi f_c C_0} = \frac{0,756}{2\pi(1000)(0,01.10^{-6})} = 12032\ \Omega$$

Stage 2 ; $(a_2 = 0,4996\ ,\ b_2 = 0,4772)$

$$R_{1,2} = \frac{a_2 C_2 \pm \sqrt{(a_2 C_2)^2 - 4 b_2 (C_1 C_2)}}{4\pi f_c C_1 C_2}$$

⊛ $C_2 > C_1 \frac{4 b_2}{a_2^{\,2}}$ → $C_2 > (0,01)\frac{4(0,4772)}{(0,4996)^2}\ .10^{-6}$

$C_2 > 0,02\ \mu F$

$C_2 = 0,05\ \mu F$

⊛ $(a_2 C_2) = 4,998.10^{-8}$

⊛ $(C_1 C_2) = 5.10^{-16}$

⊛ $(a_2 C_2)^2 = 2,49.10^{-15}$

$$R_{1,2} = \frac{9{,}998 \cdot 10^{-8} \pm \sqrt{2{,}49 \cdot 10^{-15} - 9(0{,}9772)(5 \cdot 10^{-16})}}{9\pi(1000)(5 \cdot 10^{-16})}$$

$$= 10^{12}\,\frac{9{,}998 \cdot 10^{-8} \pm \sqrt{2{,}49 \cdot 10^{-15} - 0{,}9549 \cdot 10^{-15}}}{2\pi}$$

$$= 10^{12}\,\frac{9{,}998 \cdot 10^{-8} \pm 3{,}918 \cdot 10^{-8}}{2\pi} = \frac{9{,}998 \pm 3{,}918}{2\pi} \cdot 10^{9}$$

$$R_1 = \frac{9{,}998 + 3{,}918}{2\pi} \cdot 10^{9} = 1919052$$

$$R_2 = \frac{9{,}998 - 3{,}918}{2\pi} \cdot 10^{9} = 1718\,\Omega$$

(c) Chebychev 3-dB

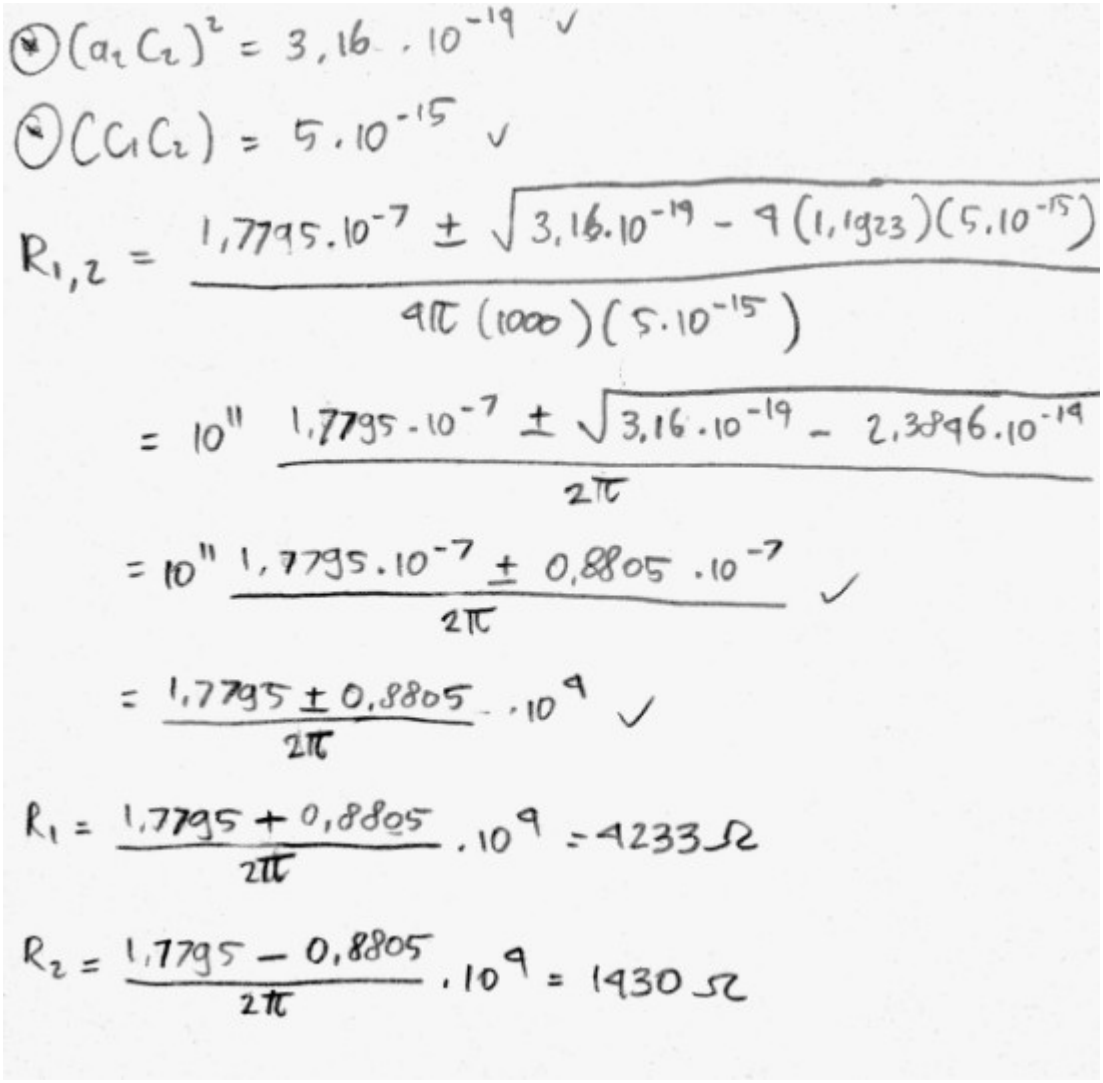
Stage 1 ($a_1 = 3{,}3996$)

$$R = \frac{a_1}{2\pi f_c C_0} = \frac{3{,}3996}{2\pi(1000)(0{,}01 \cdot 10^{-6})} = 53310\,\Omega \;\checkmark$$

Stage 2 ; ($a_2 = 0{,}3559$, $b_2 = 1{,}1923$)

$$R_{1,2} = \frac{a_2 C_2 \pm \sqrt{(a_2 C_2)^2 - 4 b_2 C_1 C_2}}{4\pi f_c C_1 C_2}$$

$$C_2 > C_1 \frac{4 b_2}{a_2^2} \rightarrow C_2 > 0{,}01 \frac{4(1{,}1923)}{(0{,}3559)^2} \cdot 10^{-6}$$



Hasil percobaan:

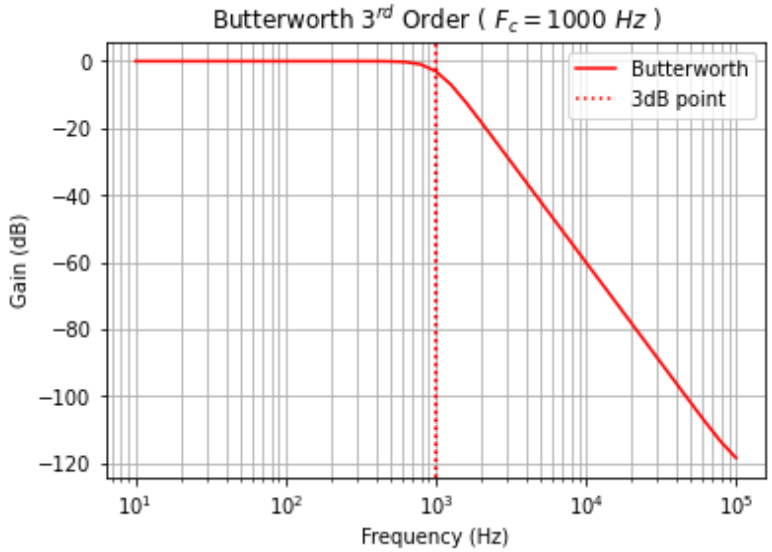
Vcc = 9 volt; f_{cutoff} = 1000 Hz; C0 = C1 = 0,01μF

Tabel 3.2

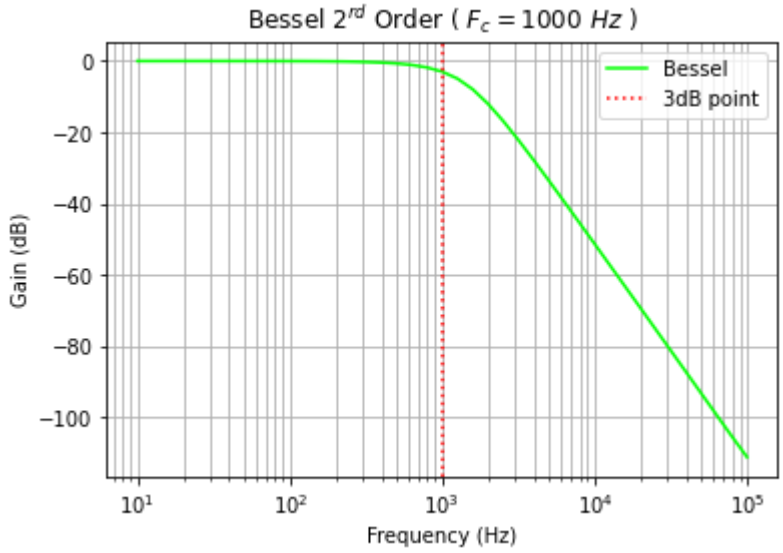
Vin (Vpeak)	Fin (Hz)	Fout (Hz)	Vout (Vpeak)		
			Butterworth	**Bessel**	**Chebychev**
			R_0= 15915 Ω C_2= 0.05 uF R_1= 11506 Ω R_2= 4408 Ω	R_0= 12032 Ω C_2= 0.05 uF R_1= 14190 Ω R_2= 1718 Ω	R_0= 53310 Ω C_2= 0.5 uF R_1= 4233 Ω R_2= 1430 Ω
5V	10	10	4.99	4.99	4.99
	100	100	4.98	4.97	4.78
	1000	1000	3.41	3.58	2.63
	10000	10000	0.0051	0.003	0.0083

- Grafik respon frekuensi terhadap gain dalam skala logaritmik (diagram Bode) LPF orde 3:

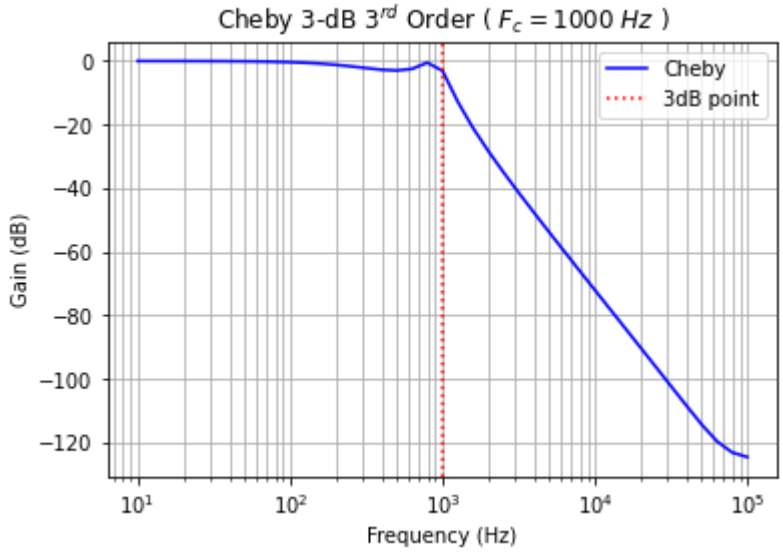
Butterworth



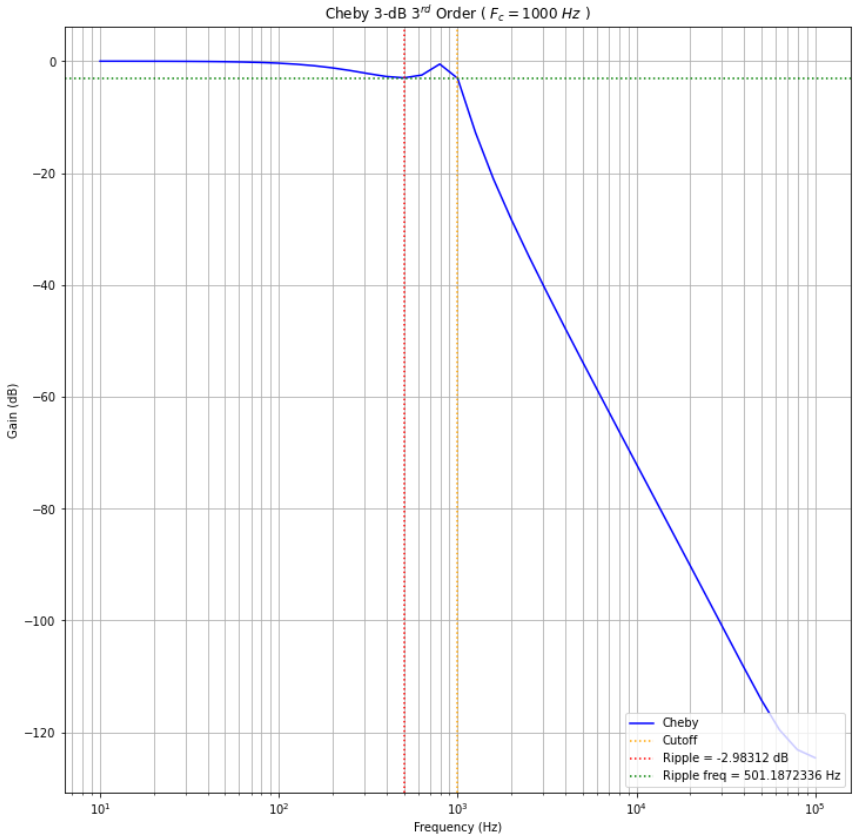
Bessel



Chebychev

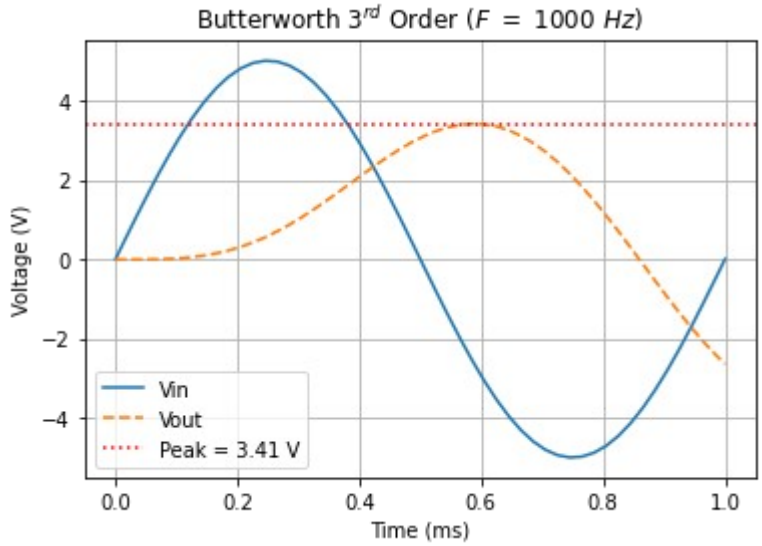


- Puncak *ripple* LPF Chebychev pada frekuensi input = **501.1872336 Hz**, dengan Gain = **-2.98312 dB**, amplitudo output LPF = **3.546614655 V_{peak}**

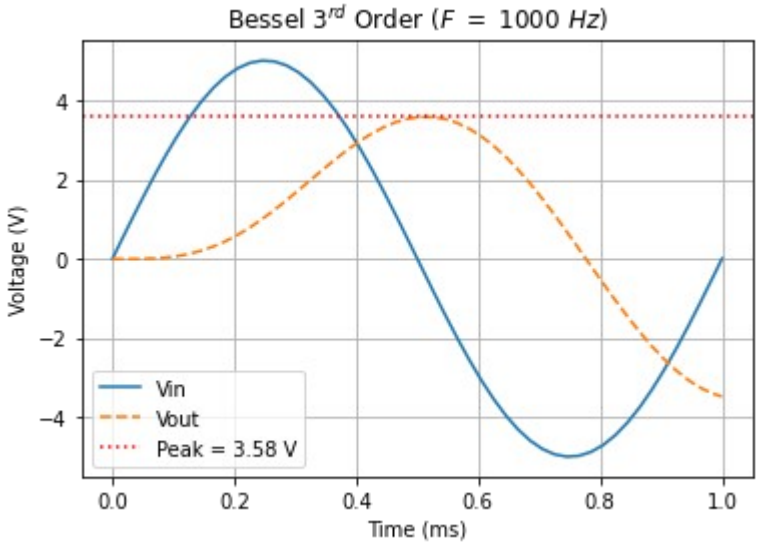


- Gambarkan bentuk gelombang input dan output (time domain) LPF saat frekuensi cutoff :

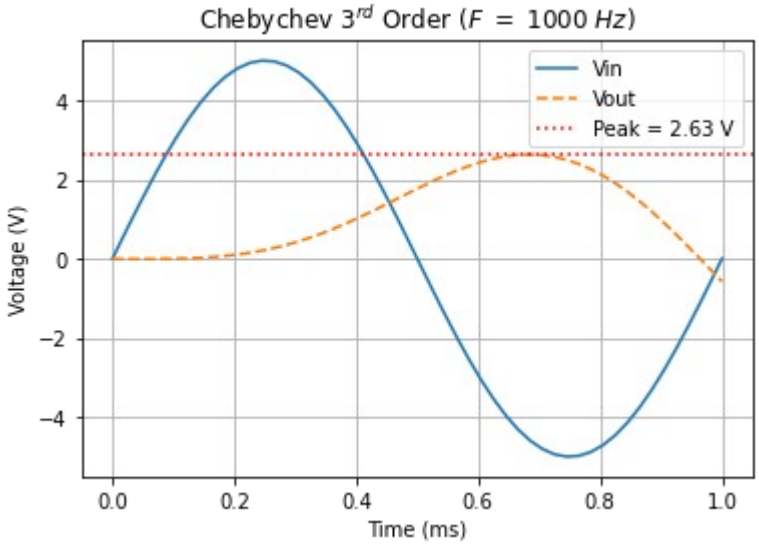
Butterworth



Bessel

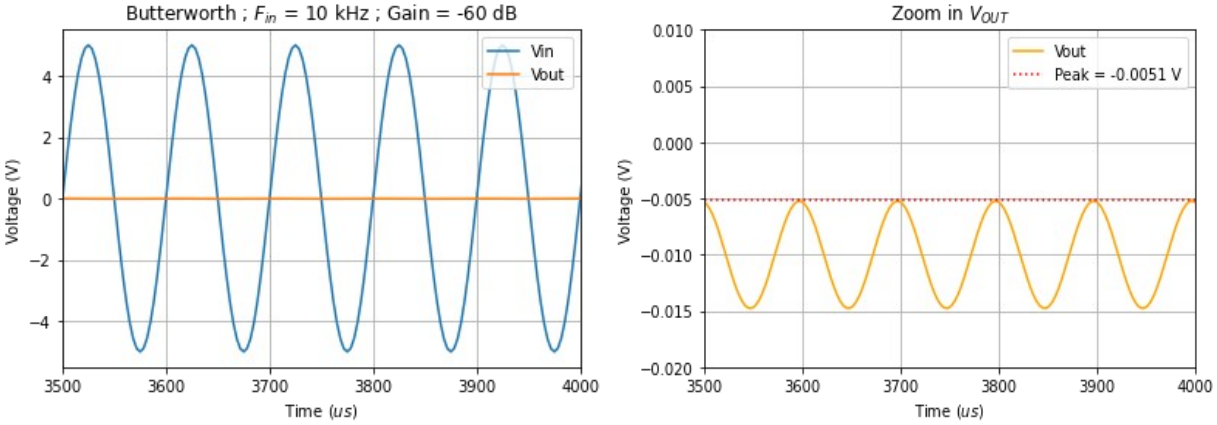


Chebychev 3-dB

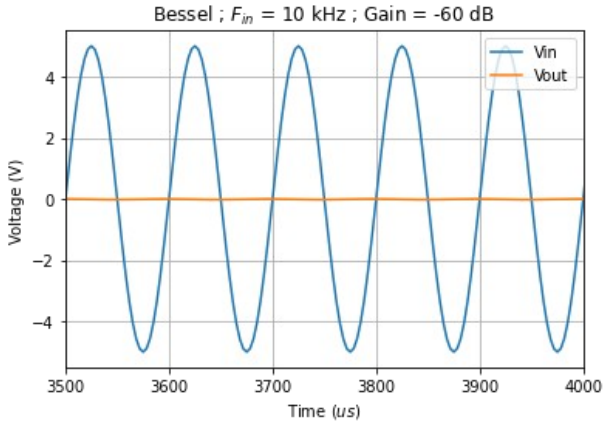


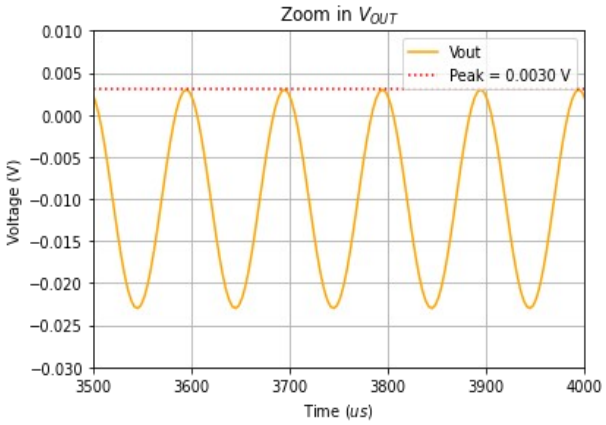
- Gambarkan bentuk gelombang input dan output (time domain) LPF saat Gain = -60dB:

Butterworth

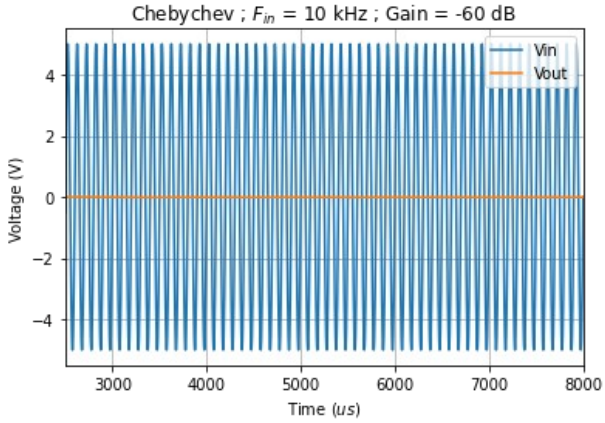


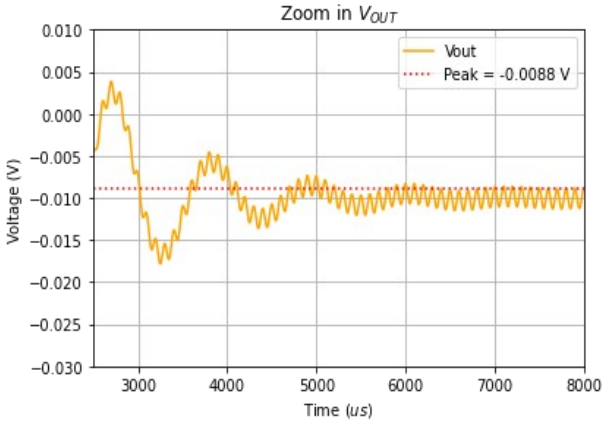
Bessel





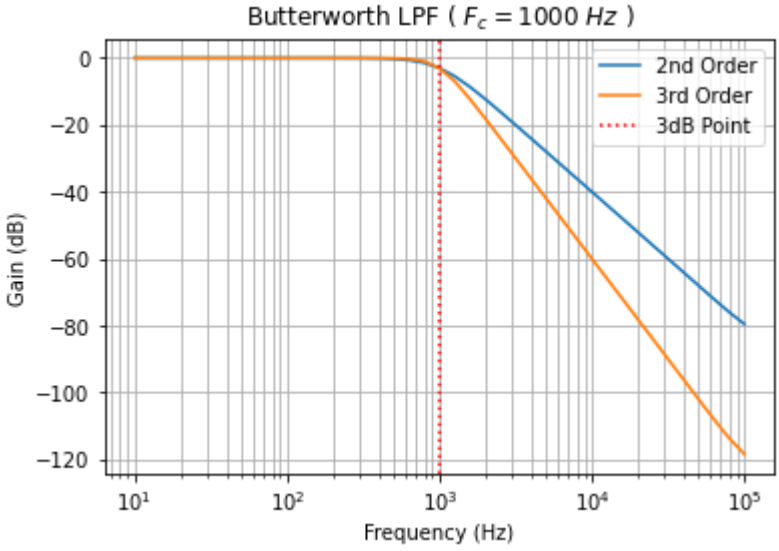
Cheby

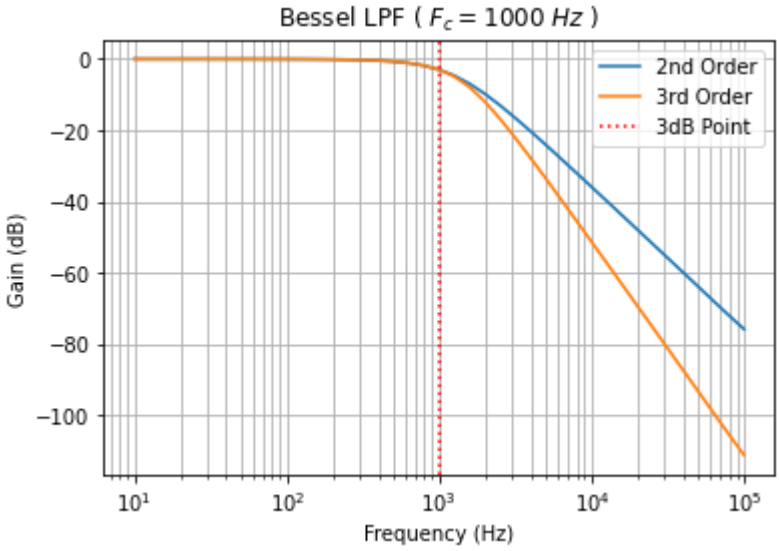


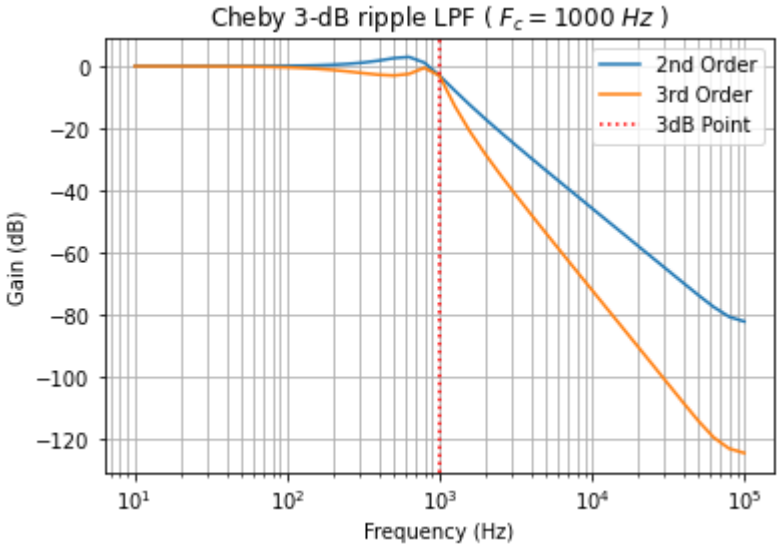


Analisa dan kesimpulan

Jika dibandingkan secara berjajar, untuk tiap-tipa jenis filter dan orde nya:

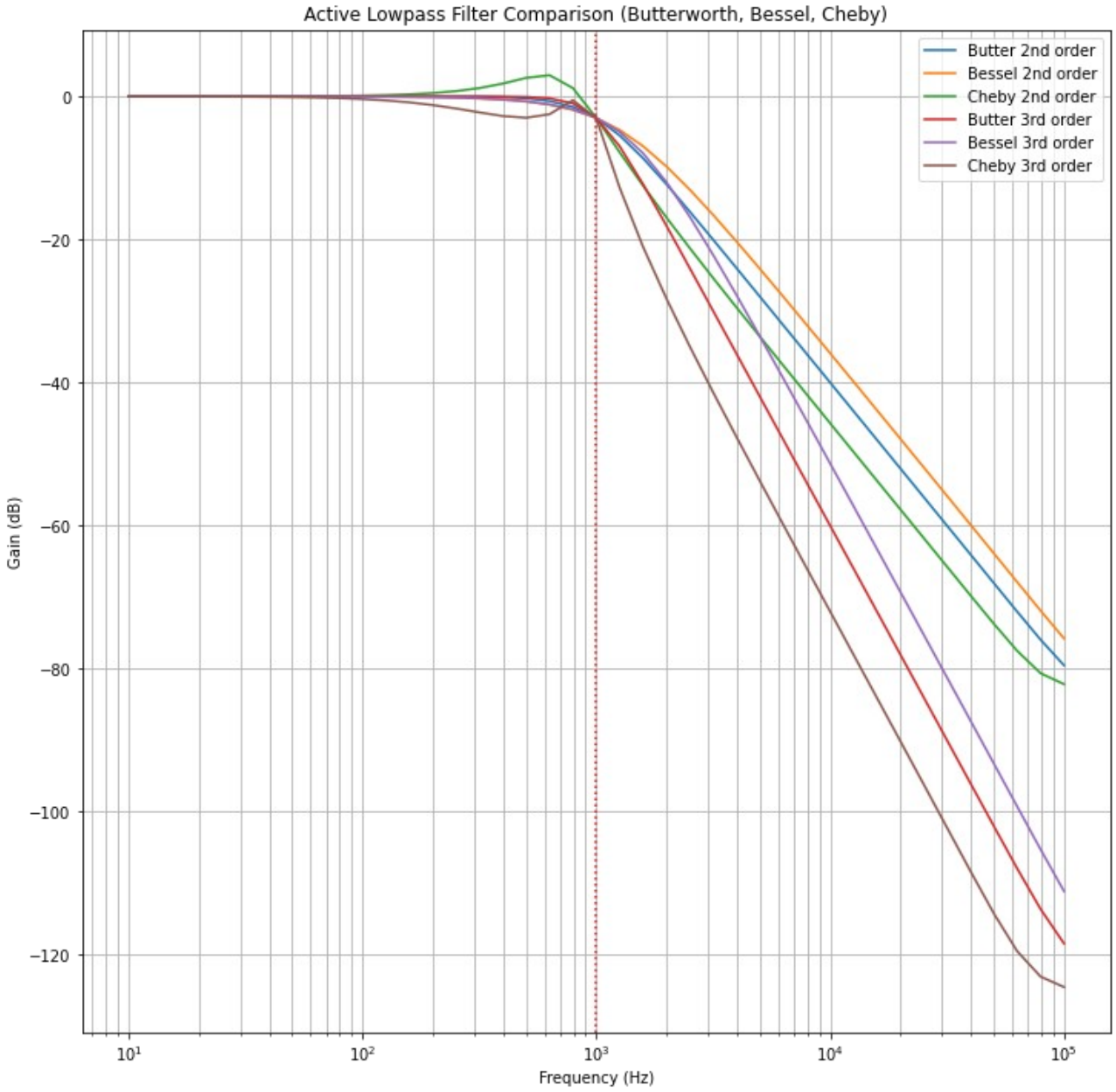






Dapat disimpulkan bahwa semakin tinggi orde filter, maka roll-off peredaman akan semakin curam. Untuk orde 2 memiliki peredaman sebesar 40 dB / decade, dan untuk orde 3 memiliki peredaman sebesar 40 dB / decade. Arti dari **x dB / decade** adalah ”untuk setiap kelipatan 10 dari frekuensi setelah melewati cutoff, maka output akan semakin diredam sebesar **x dB** ”.

Grafik Perbandingan Filter Keseluruhan



Kesimpulan

- Filter orde 1 memberikan peredaman sebesar 40 dB / decade
- Filter orde 2 memberikan peredaman sebesar 40 dB / decade.
- Filter orde 3 memberikan peredaman sebesar 60 dB / decade
- Desain filter dengan orde > 3 dilakukan dengan cascade filter orde 1 & 2.

- Karakteristik jenis filter pada praktikum Modul 3:
    - **Butterworth**: Passband *flat*, roll-off sedang, paling mudah di desain, memiliki phase shift.
    - **Bessel** : Passband *flat*, roll-off sangat lambat, namun memiliki kelebihan phase shift kecil.
    - **Chebychev** : Passband tidak *flat*, roll-of sangat cepat, memiliki phase shift.

Lampiran (Tugas Awal)