Filtros Elétricos

Simulação de Filtros Elétricos

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Prof. Dr. Cleonílson Protásio Souza

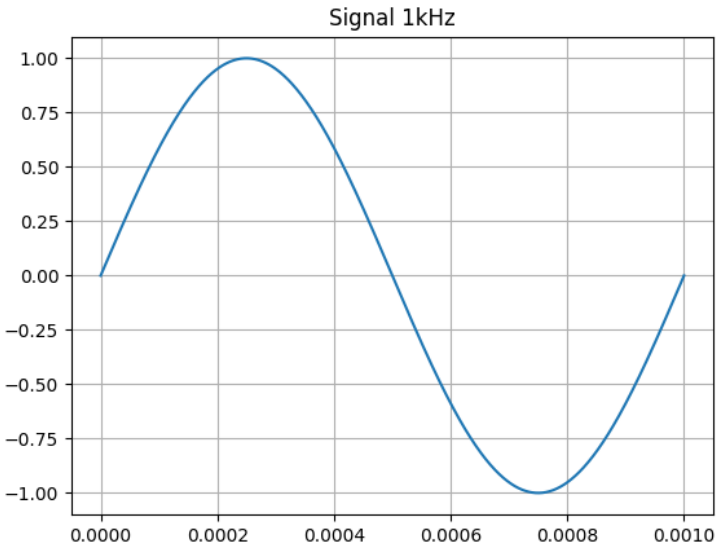
Objetivos

- Objetivo: Simulação da remoção de ruídos utilizando filtros.
- Código disponível em: https://github.com/V-kr0pt/filtros_ufpb.

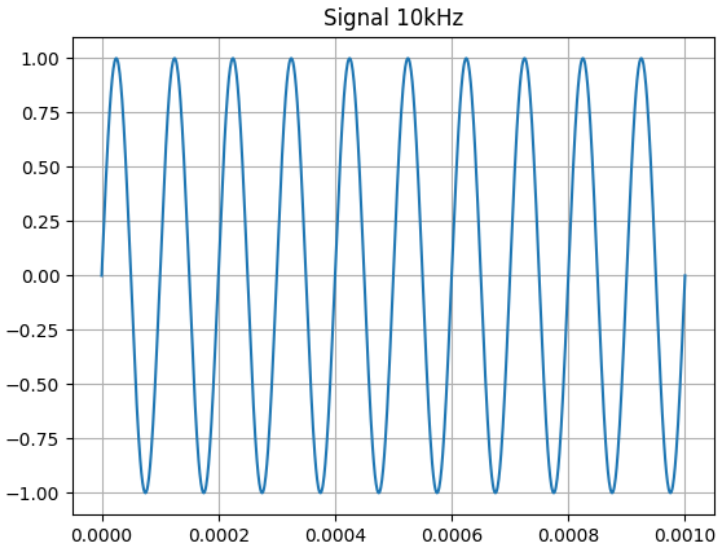
Introdução

- Filtros elétricos são dispositivos utilizados para permitir ou bloquear diferentes faixas de frequências.
- Utilizados para remover ruídos indesejados em circuitos eletrônicos.
- Classificação: Filtros Passivos (R, L, C) e Filtros Ativos (incluem Amplificadores Operacionais).

Sinais de Interesse

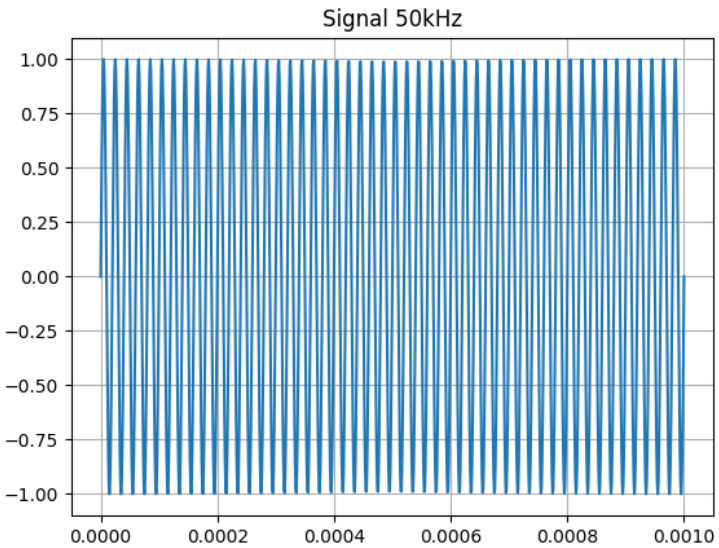


(a) Sinal senoidal de 1kHz

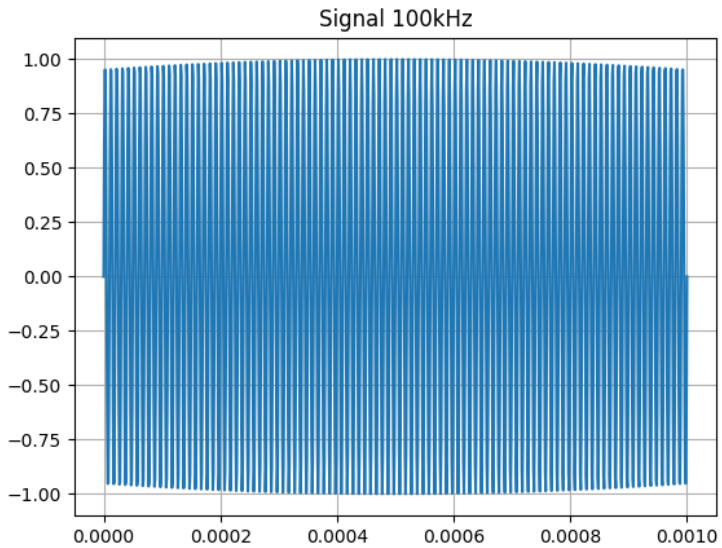


(b) Sinal senoidal de 10kHz

Sinais de Interesse

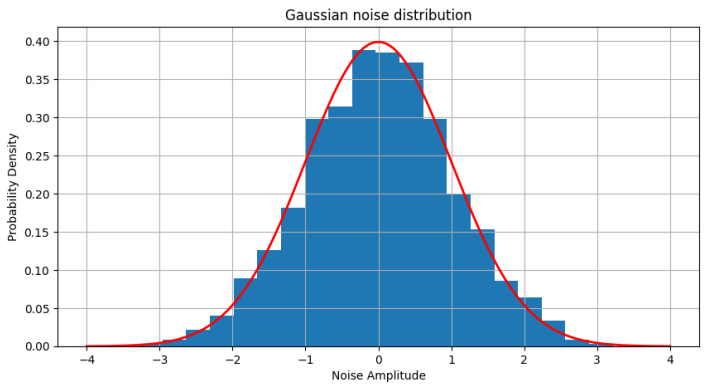


(a) Sinal senoidal de 50kHz

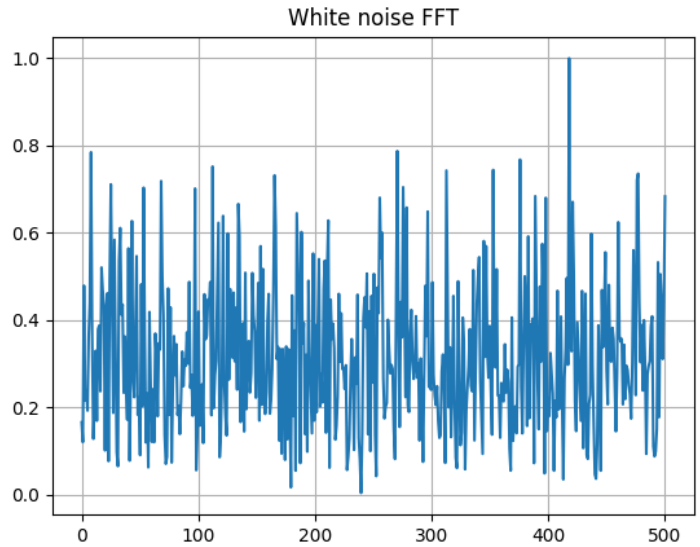


(b) Sinal senoidal de 100kHz

Ruído Gaussiano Branco



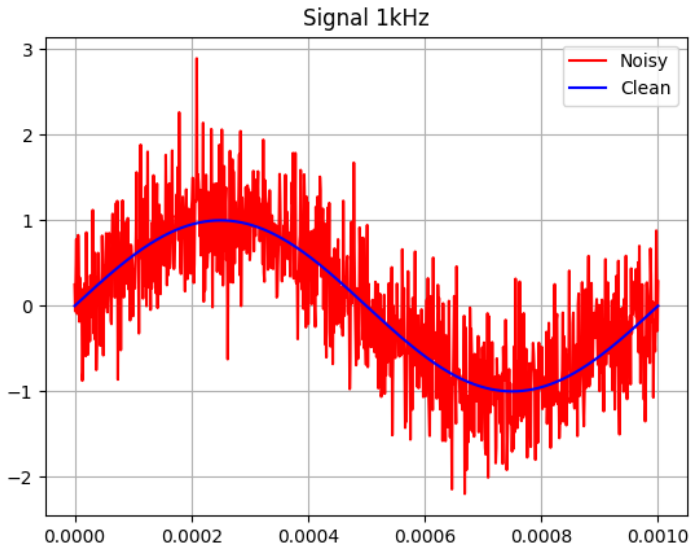
(a) Histograma do ruído gerado



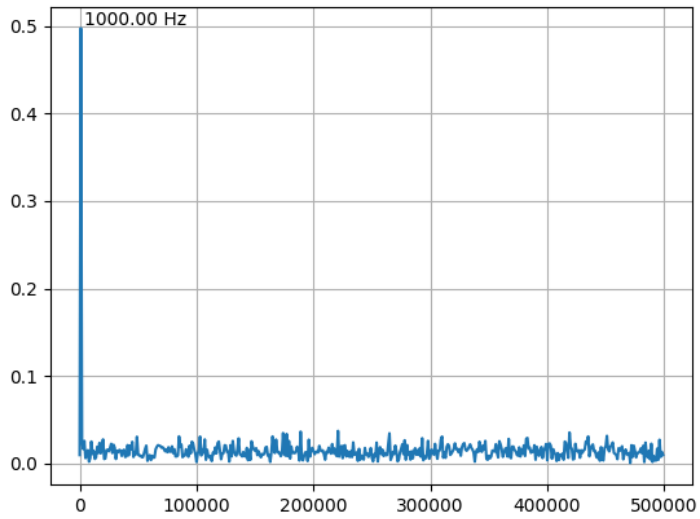
(b) Ruído no domínio da frequência

Figura: Ruído Gaussiano Branco

Sinais de Interesse com Ruído

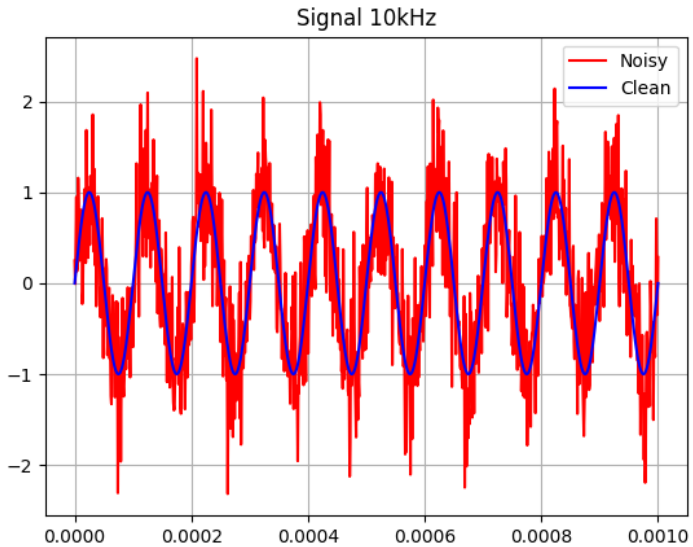


(a) Sinal de 1kHz com ruído

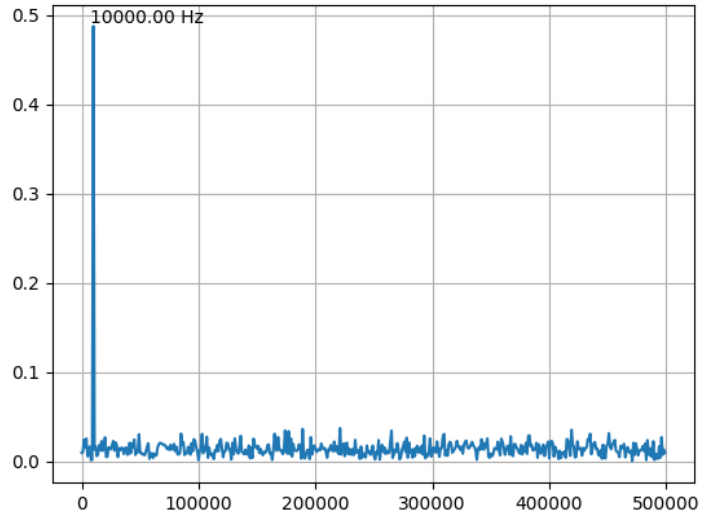


(b) Sinal de 1kHz no domínio da frequência

Sinais de Interesse com Ruído

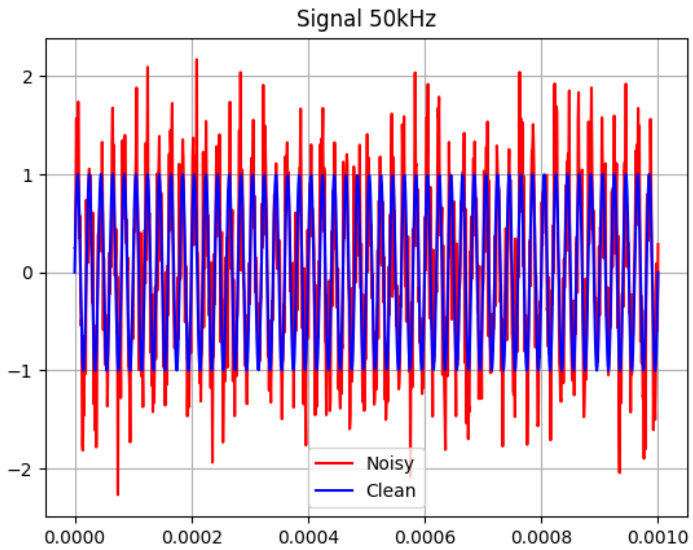


(a) Sinal de 10kHz com ruído

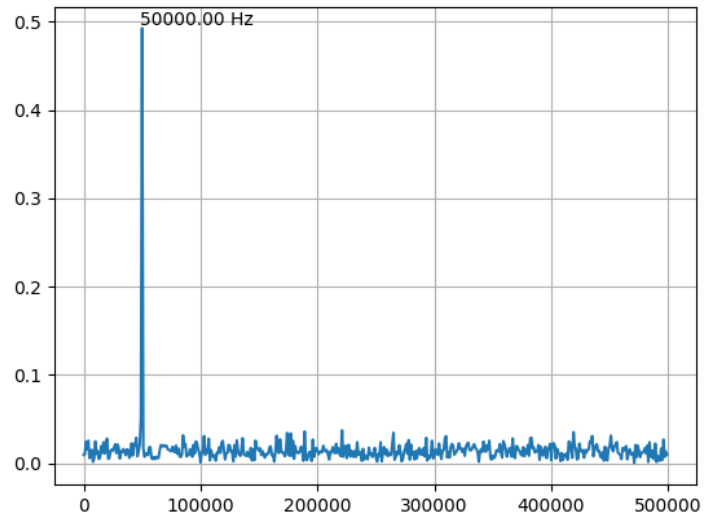


(b) Sinal de 10kHz no domínio da frequência

Sinais de Interesse com Ruído

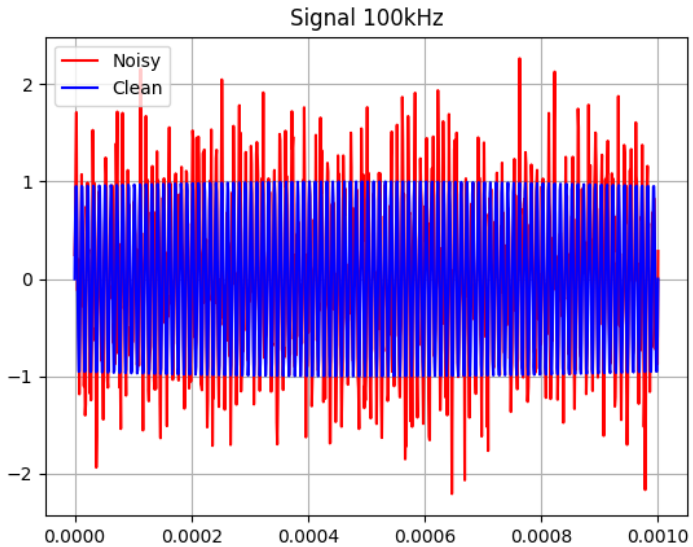


(a) Sinal de 50kHz com ruído

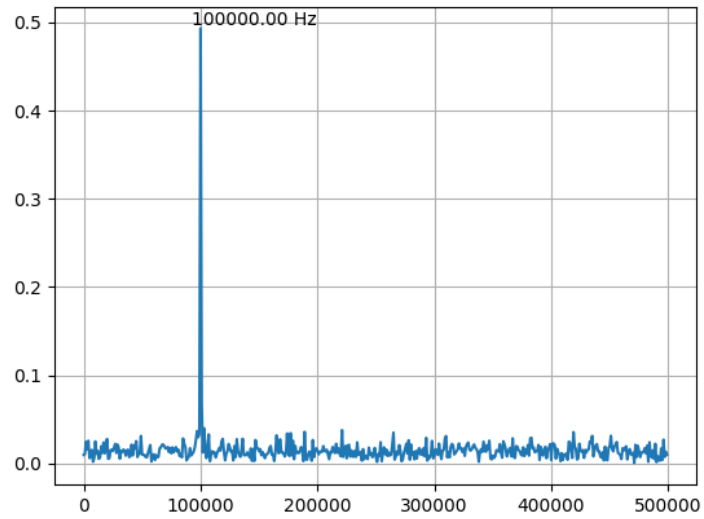


(b) Sinal de 50kHz no domínio da frequência

Sinais de Interesse com Ruído



(a) Sinal de 100kHz com ruído



(b) Sinal de 100kHz no domínio da frequência

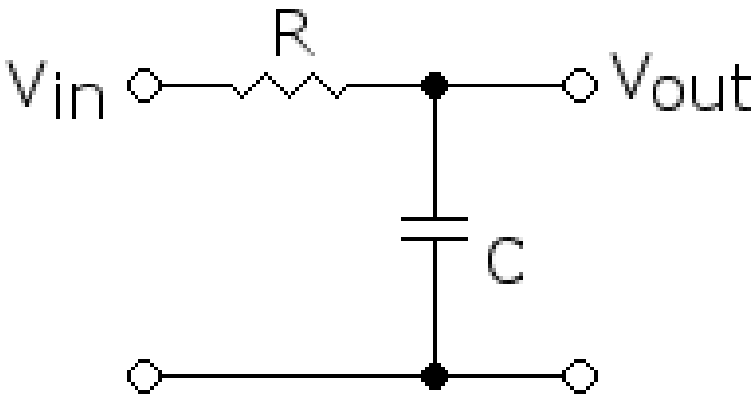
Relação Sinal-Ruído (SNR)

$$SNR(dB) = 10 \log \left(\frac{P_s}{P_n} \right) \tag{1}$$

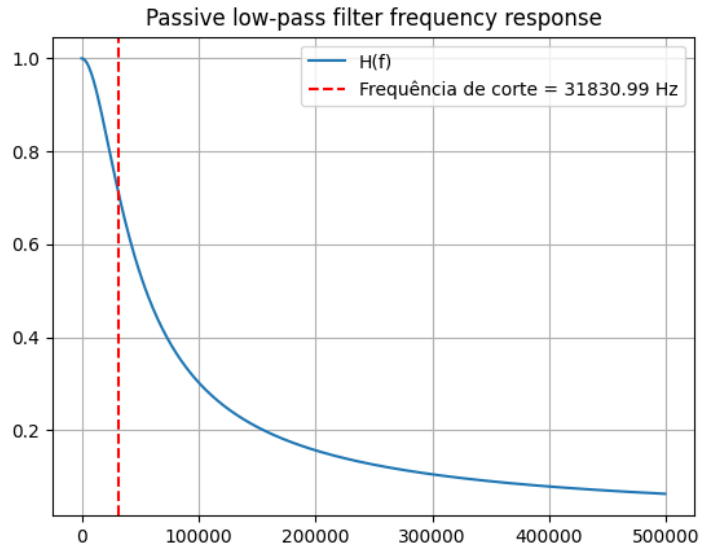
$$SNR(dB) = 10 \log \left(\frac{P_s^{out}}{P_{s+n}^{out} - P_s^{out}} \right) \tag{2}$$

- SNR do sinal de entrada: 3,19 dB
- Comparação da eficácia dos filtros utilizando SNR.

Filtro Passa-Baixa Passivo



(a) Circuito do filtro

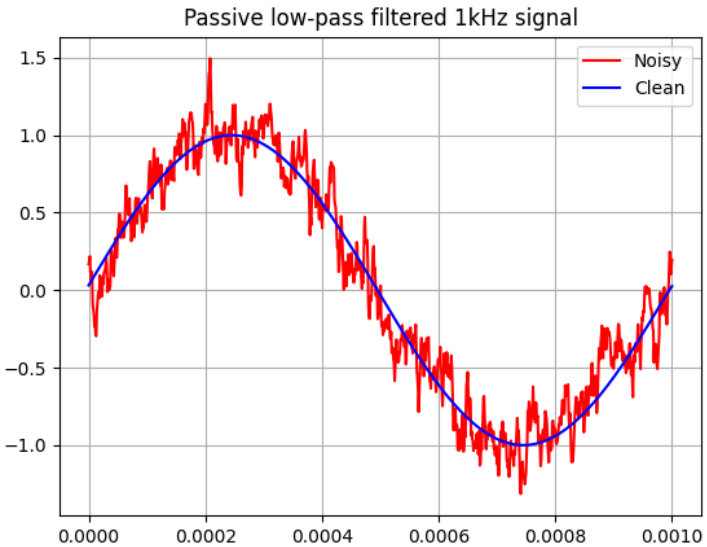


(b) Resposta em frequência

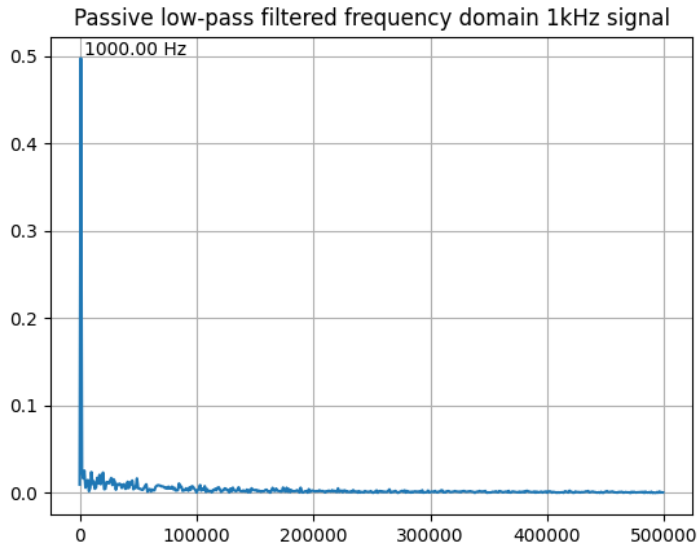
$$\frac{V_{out}}{V_{in}} = \frac{-\frac{1}{RC}}{s - \frac{1}{RC}} \tag{3}$$

$$f_c = \frac{1}{2\pi RC},\ R = 5k\Omega \text{ e } C = 1nF \implies f_c = 31,8\text{kHz} \approx 30\text{kHz}$$

Sinais Filtrados: Filtro Passa-Baixa Passivo

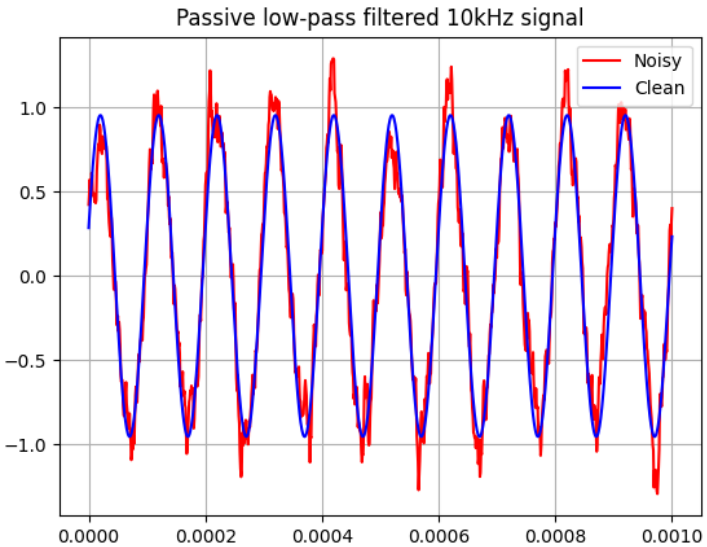


(a) Sinal de 1kHz filtrado

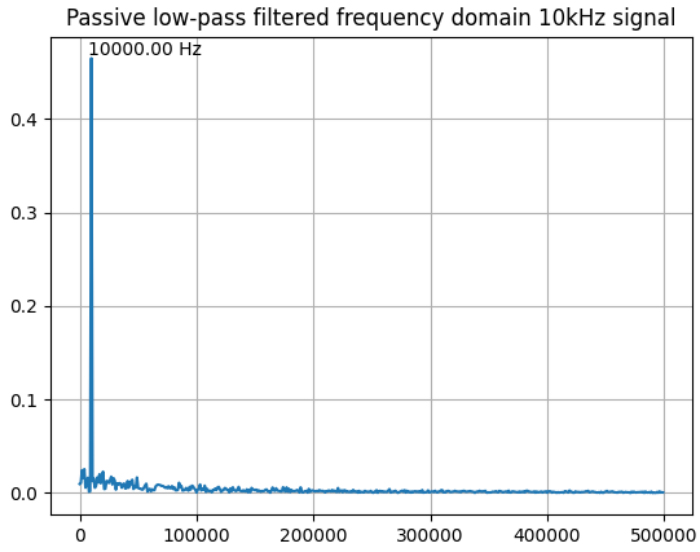


(b) Sinal de 1kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Passivo

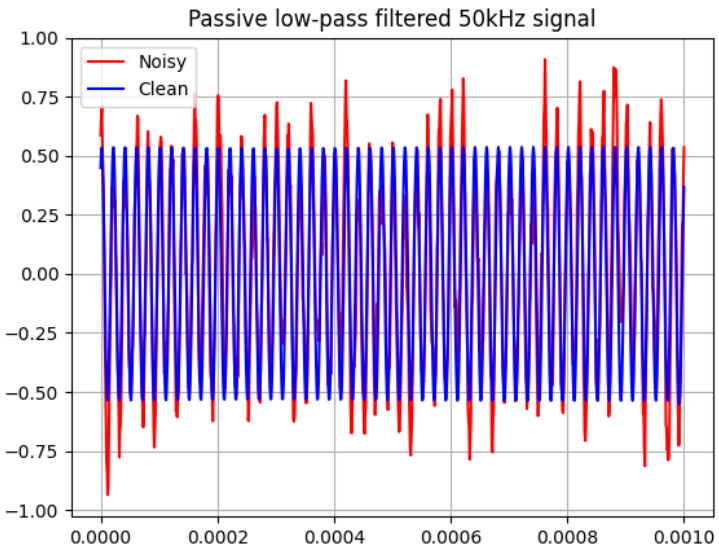


(a) Sinal de 10kHz filtrado

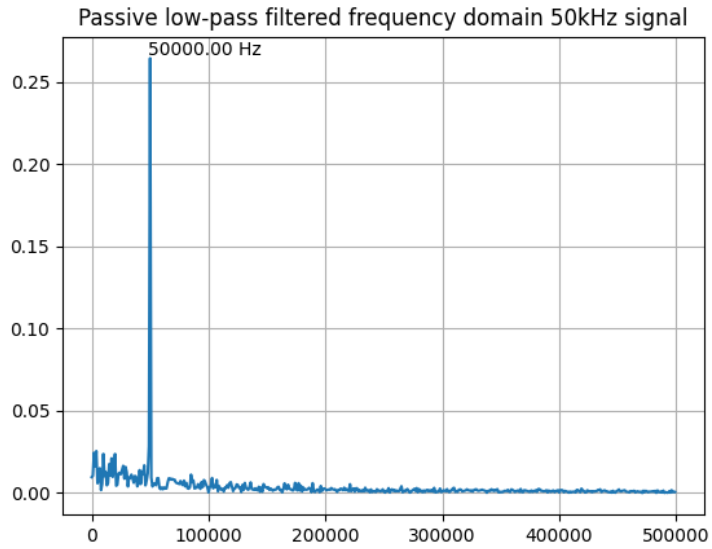


(b) Sinal de 10kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Passivo

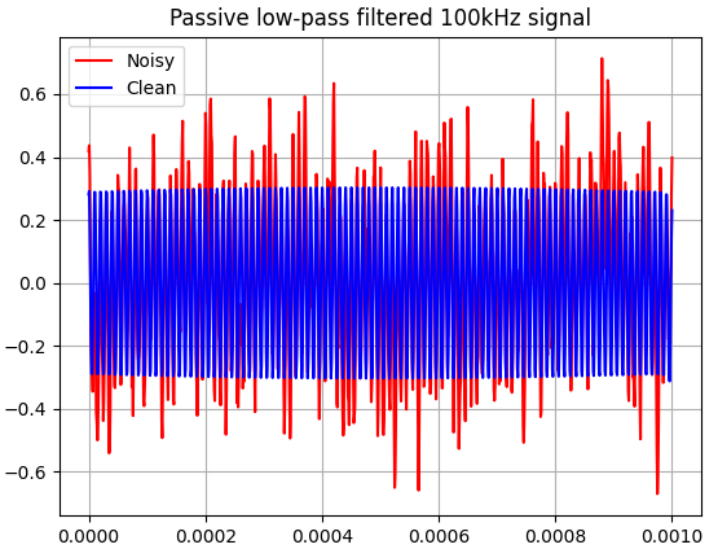


(a) Sinal de 50kHz filtrado

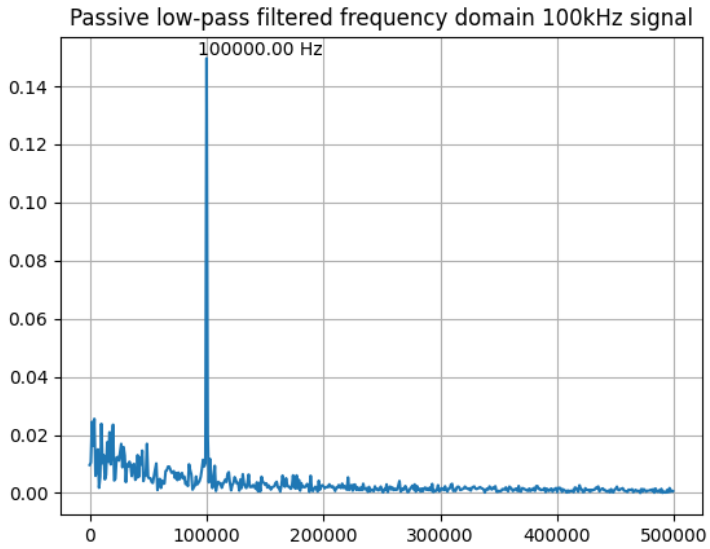


(b) Sinal de 50kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Passivo

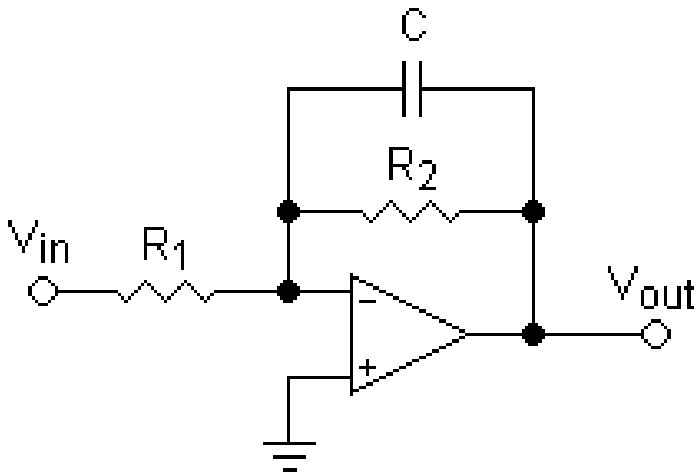


(a) Sinal de 100kHz filtrado

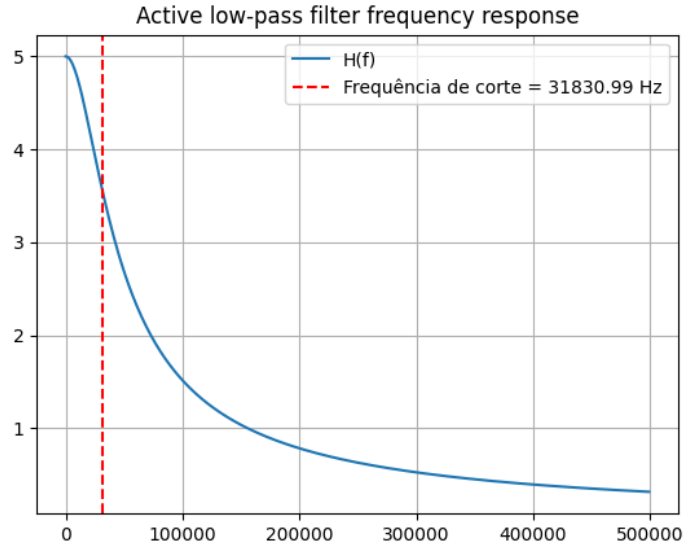


(b) Sinal de 100kHz no domínio da frequência

Filtro Passa-Baixa Ativo



(a) Circuito do filtro



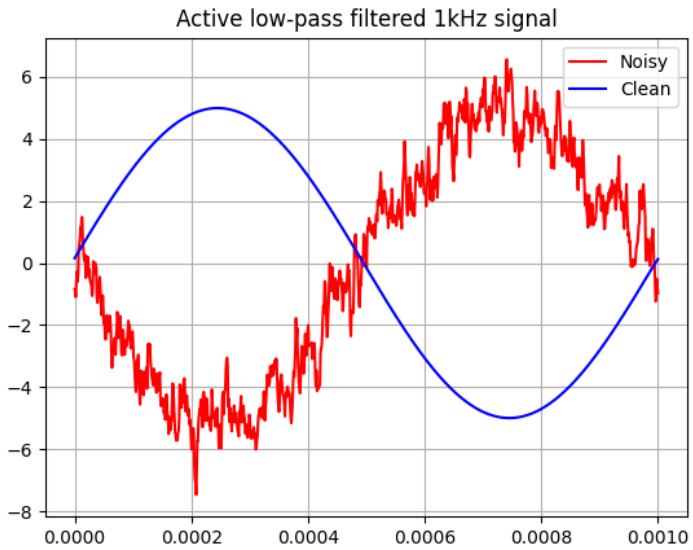
(b) Resposta em frequência

$$\frac{V_{out}}{V_{in}} = \frac{-\frac{1}{R_1 C}}{s - \frac{1}{R_2 C}} \tag{4}$$

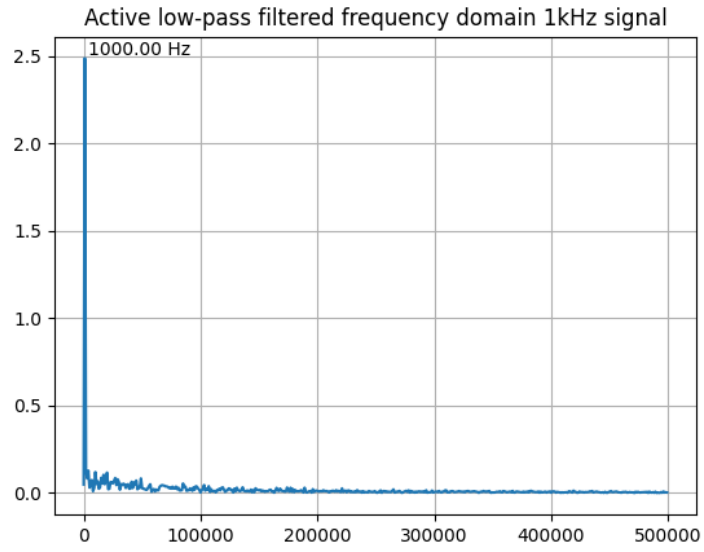
$$f_c = \frac{1}{2\pi RC},\ R_2 = 5k\Omega \text{ e } C = 1nF \implies f_c = 31,8\text{kHz} \approx 30\text{kHz}$$

$$R_1 = 1k\Omega \implies A_{dc} = -5V/V$$

Sinais Filtrados: Filtro Passa-Baixa Ativo

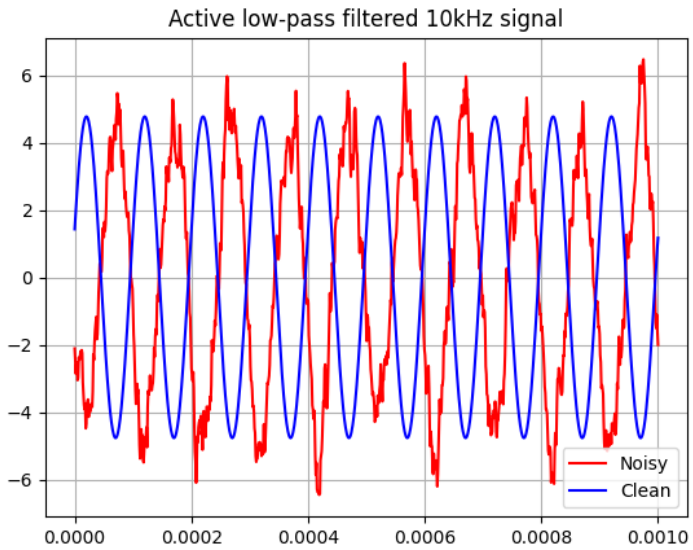


(a) Sinal de 1kHz filtrado

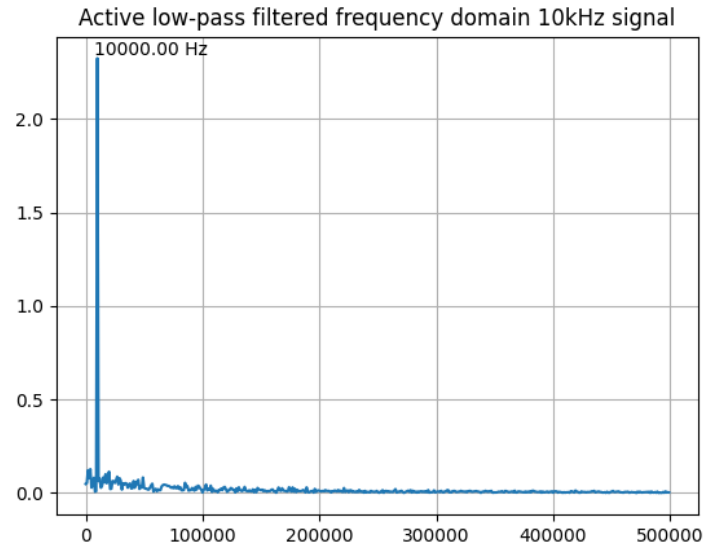


(b) Sinal de 1kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Ativo

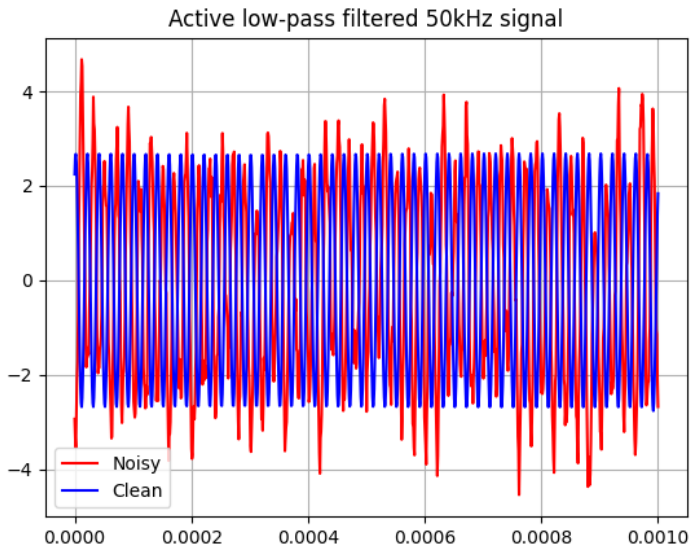


(a) Sinal de 10kHz filtrado

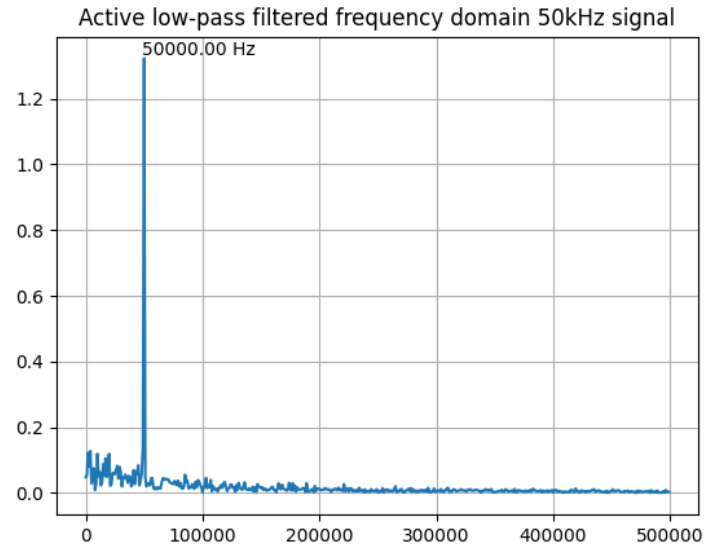


(b) Sinal de 10kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Ativo

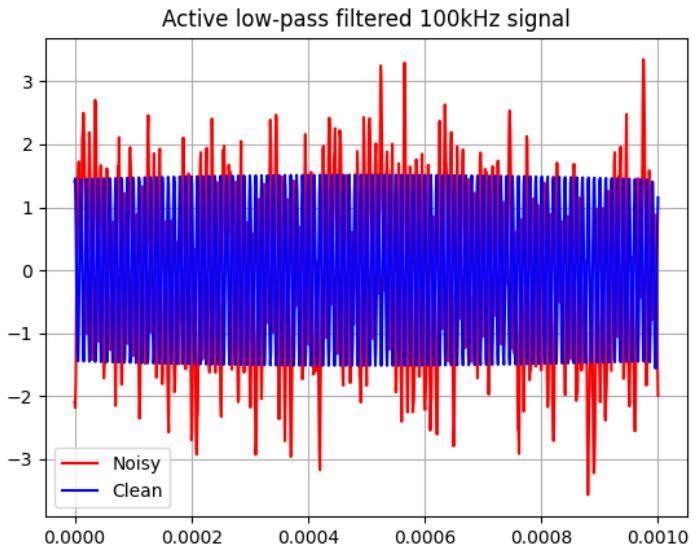


(a) Sinal de 50kHz filtrado

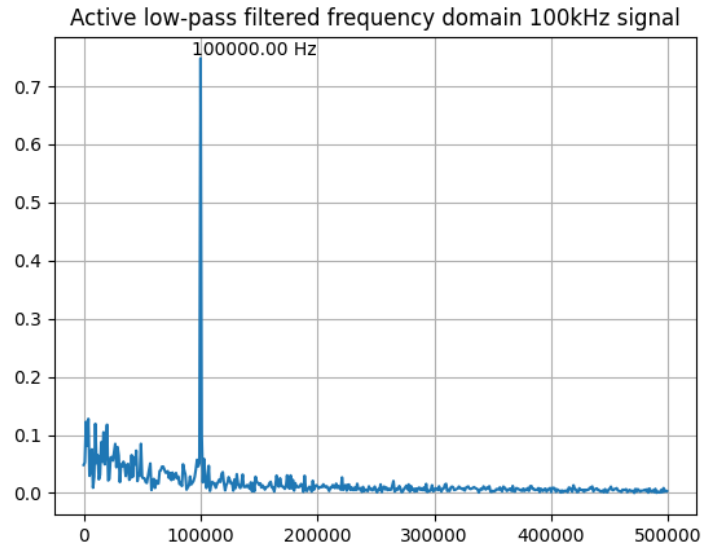


(b) Sinal de 50kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Baixa Ativo



(a) Sinal de 100kHz filtrado



(b) Sinal de 100kHz no domínio da frequência

SNR: Sinal de Saída do Filtro Passa-Baixa

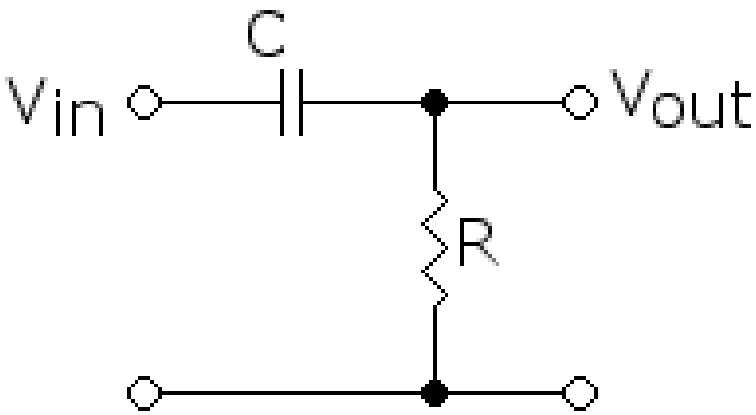
$$SNR_{1\text{kHz}} = 13.40\text{dB}$$

$$SNR_{10\text{kHz}} = 12.99\text{dB}$$

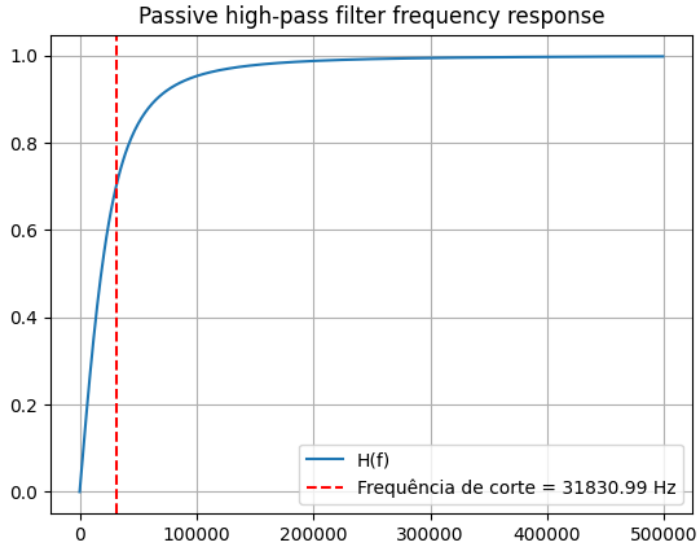
$$SNR_{50\text{kHz}} = 8.00\text{dB}$$

$$SNR_{100\text{kHz}} = 3.04\text{dB}$$

Filtro Passa-Alta Passivo



(a) Circuito do filtro

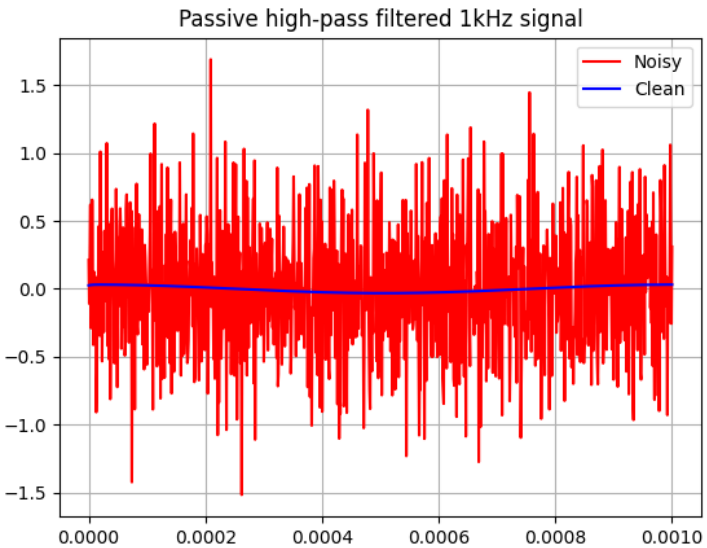


(b) Resposta em frequência

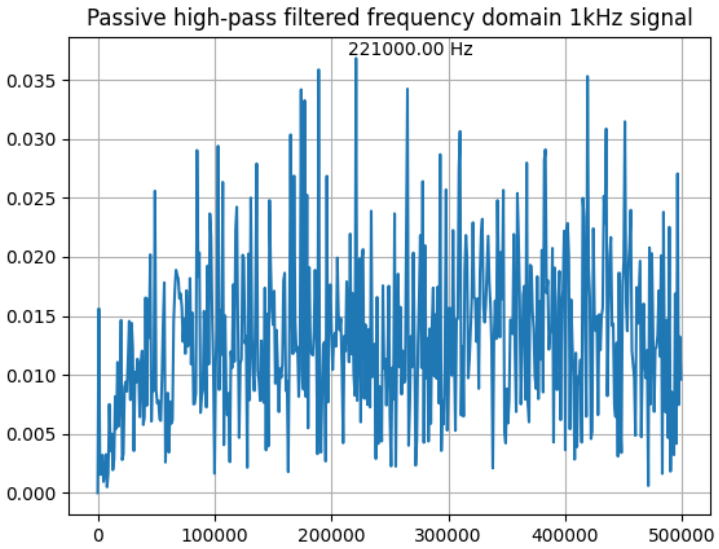
$$\frac{V_{out}}{V_{in}} = \frac{s}{s + \frac{1}{RC}} \tag{5}$$

$$f_c = \frac{1}{2\pi RC},\ R = 5k\Omega \text{ e } C = 1nF \implies f_c = 31,8\text{kHz} \approx 30\text{kHz}$$

Sinais Filtrados: Filtro Passa-Alta Passivo

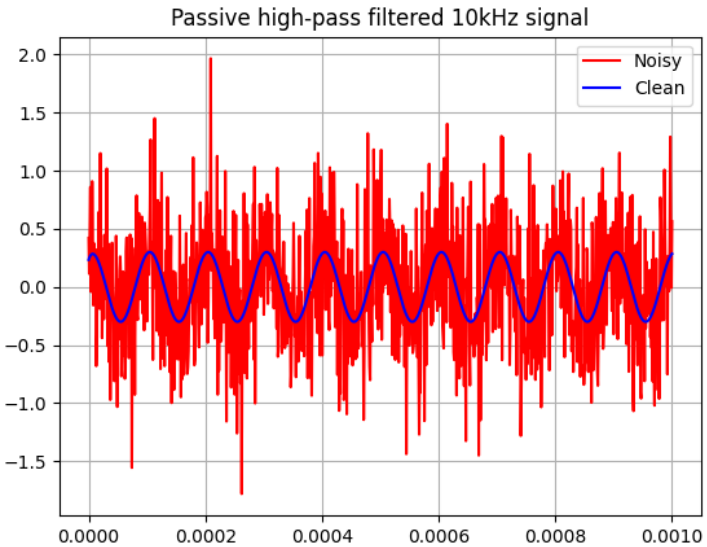


(a) Sinal de 1kHz filtrado

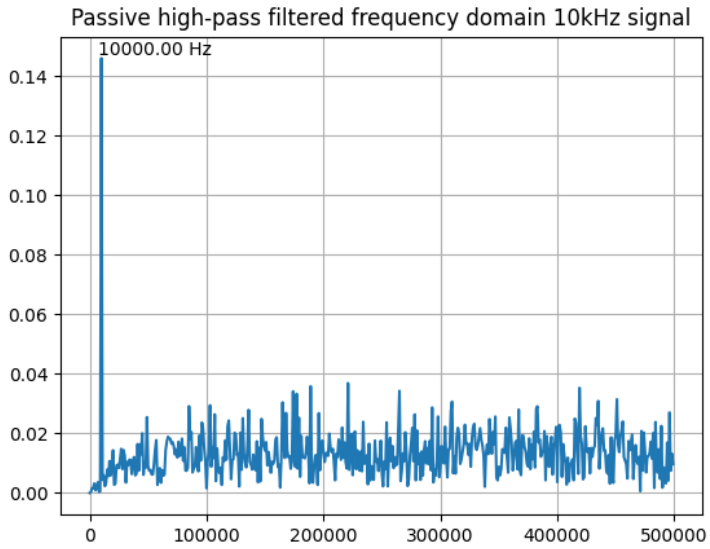


(b) Sinal de 1kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Passivo

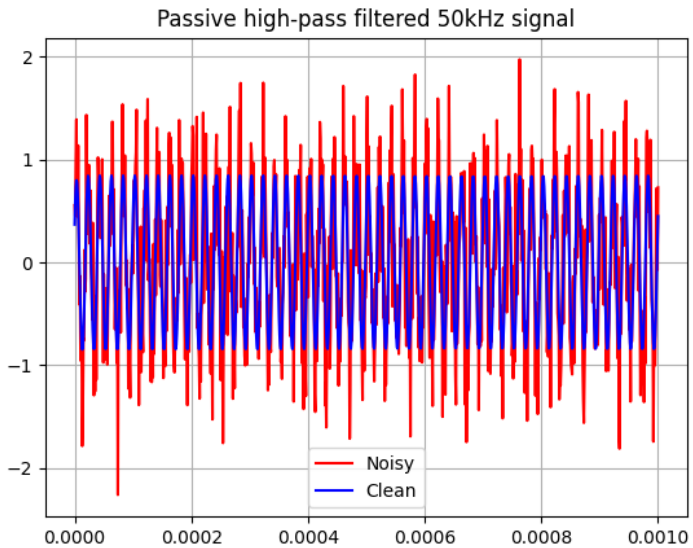


(a) Sinal de 10kHz filtrado

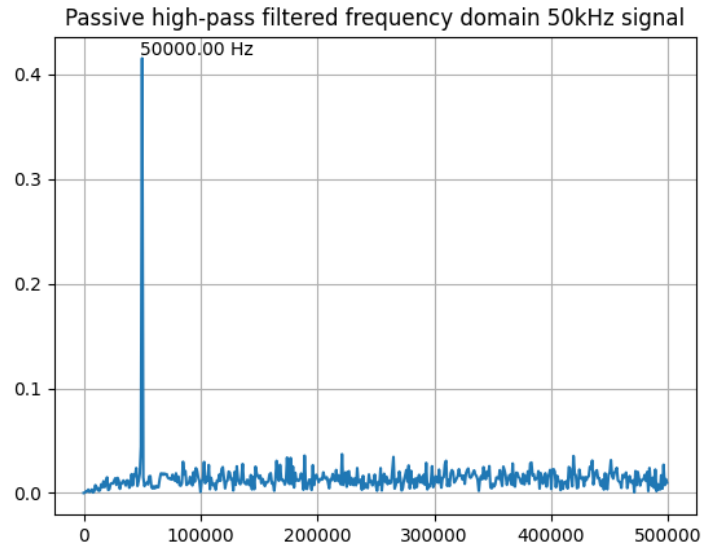


(b) Sinal de 10kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Passivo

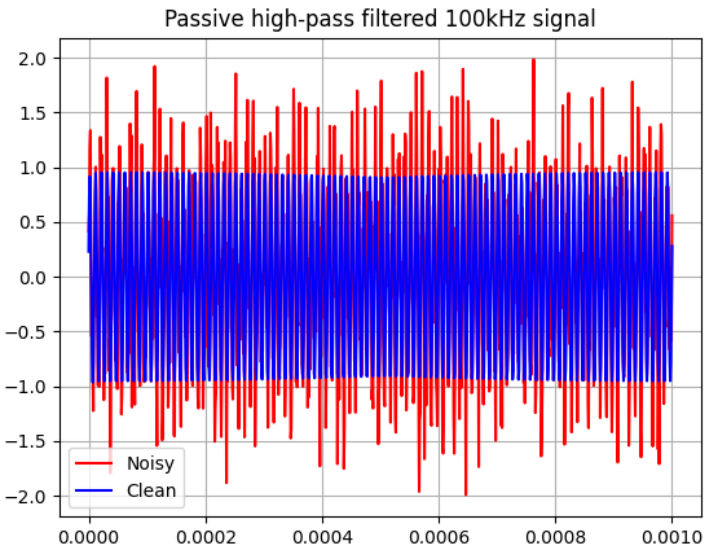


(a) Sinal de 50kHz filtrado

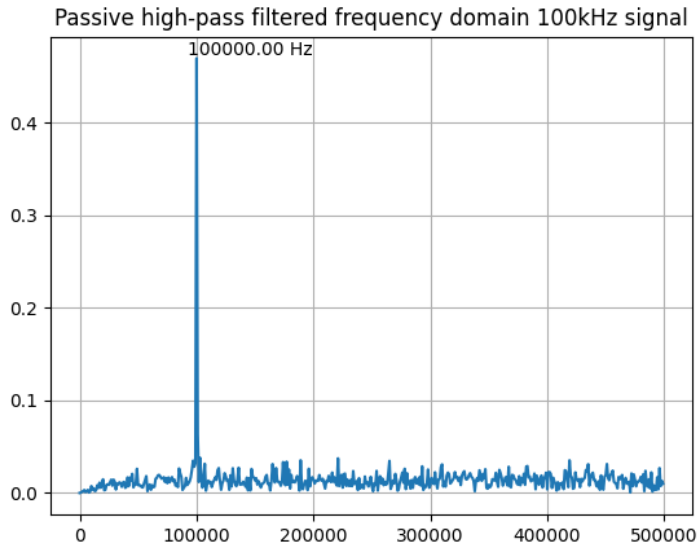


(b) Sinal de 50kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Passivo

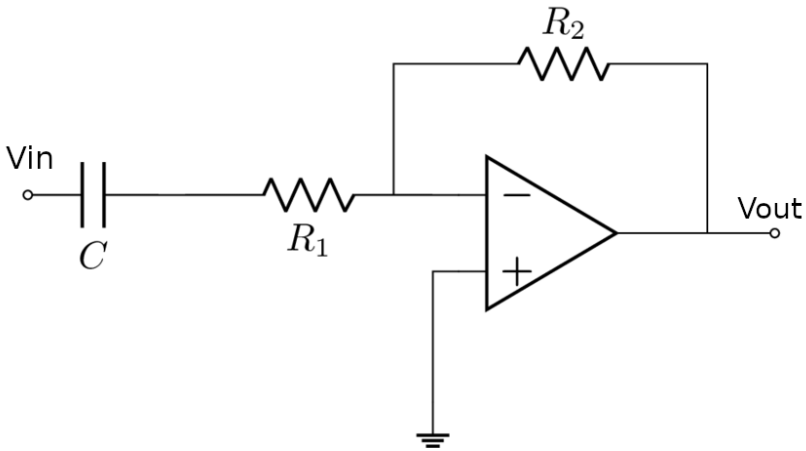


(a) Sinal de 100kHz filtrado

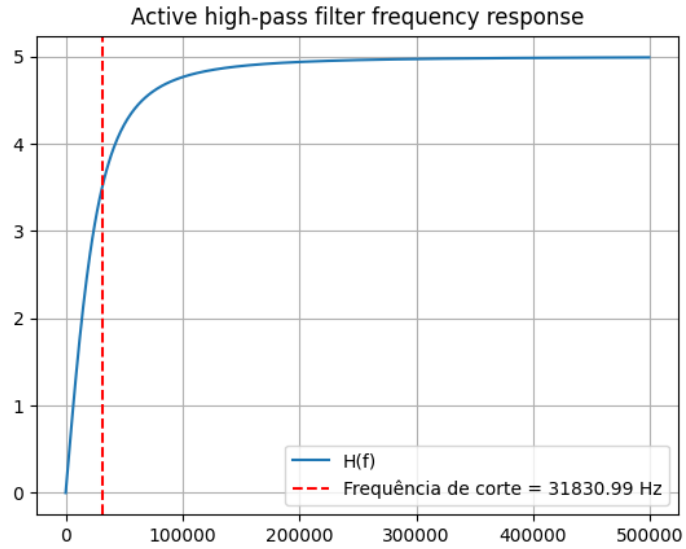


(b) Sinal de 100kHz no domínio da frequência

Filtro Passa-Alta Ativo



(a) Circuito do filtro



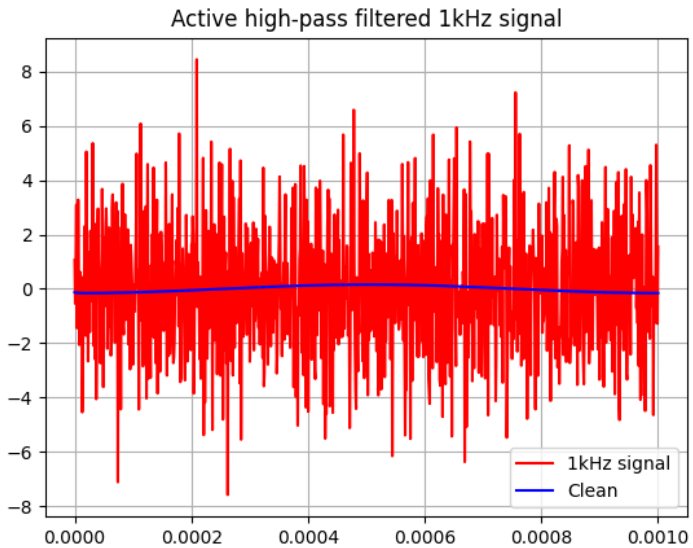
(b) Resposta em frequência

$$\frac{V_{out}}{V_{in}} = \frac{-s\frac{R_2}{R_1}}{s + \frac{1}{R_1 C}} \tag{6}$$

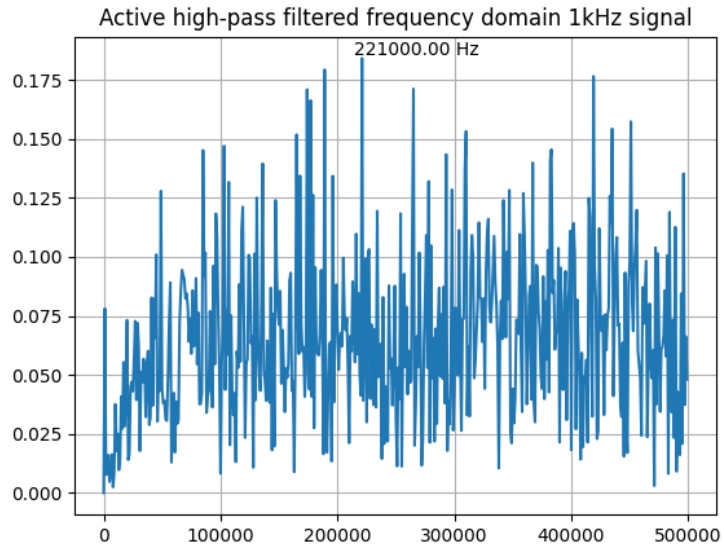
$$f_c = \frac{1}{2\pi RC},\ R_1 = 5k\Omega \text{ e } C = 1nF \implies f_c = 31,8\text{kHz} \approx 30\text{kHz}$$

$$R_2 = 25k\Omega \implies A_{s\to\infty} = -5V/V$$

Sinais Filtrados: Filtro Passa-Alta Ativo

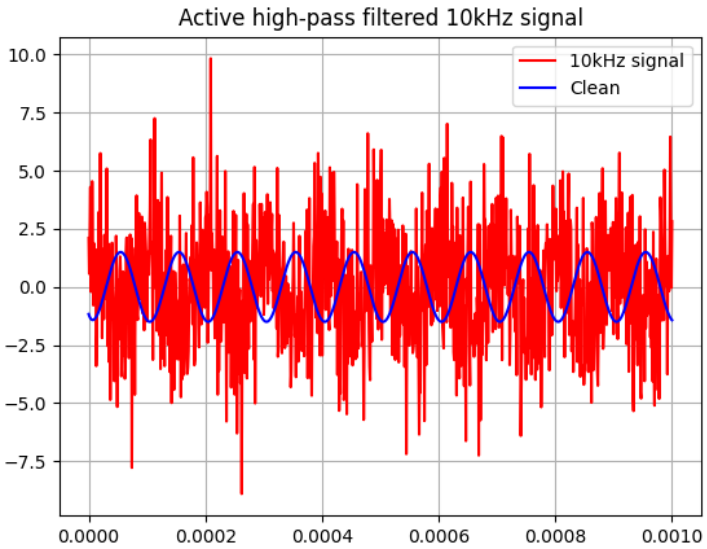


(a) Sinal de 1kHz filtrado

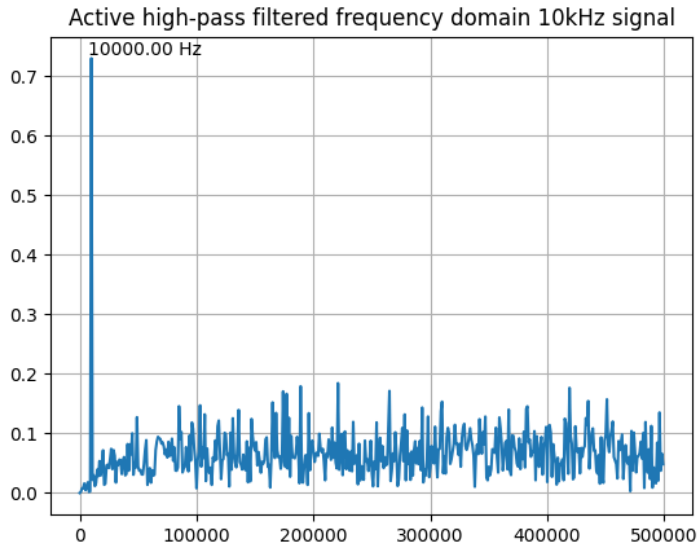


(b) Sinal de 1kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Ativo

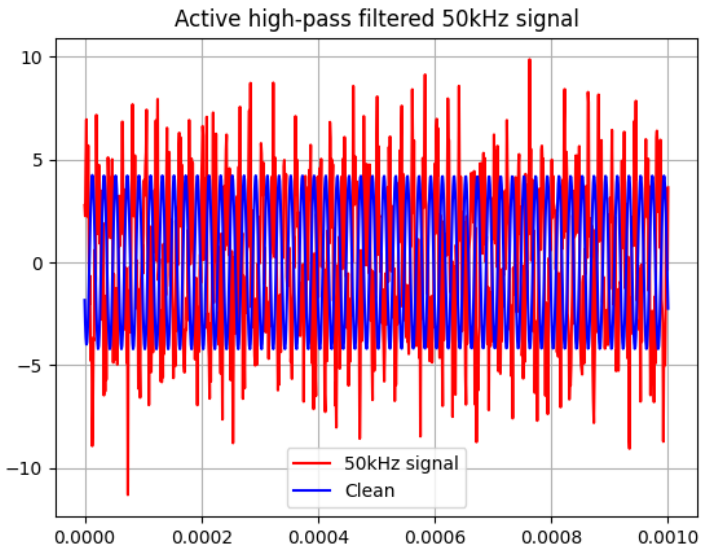


(a) Sinal de 10kHz filtrado

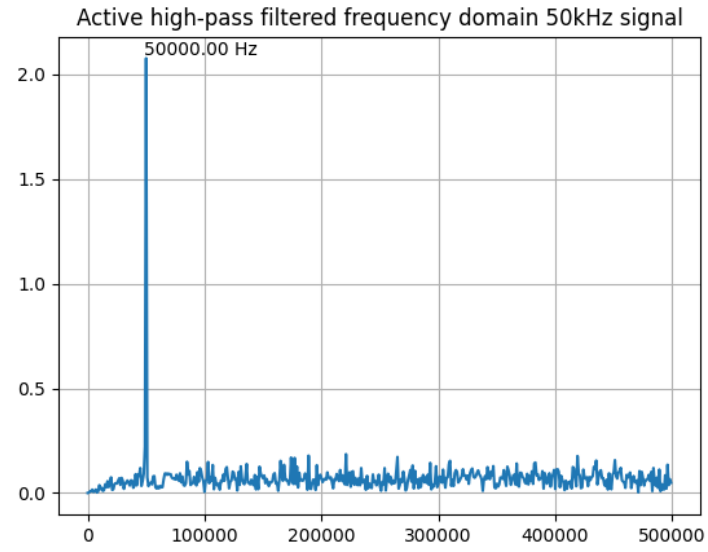


(b) Sinal de 10kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Ativo

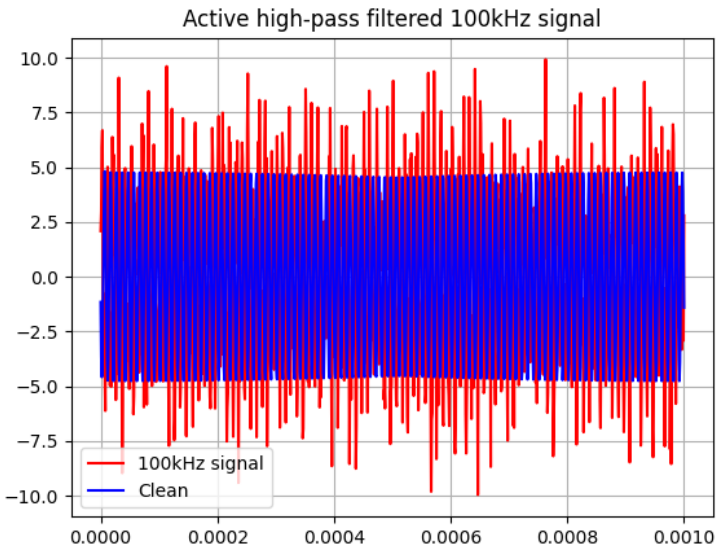


(a) Sinal de 50kHz filtrado

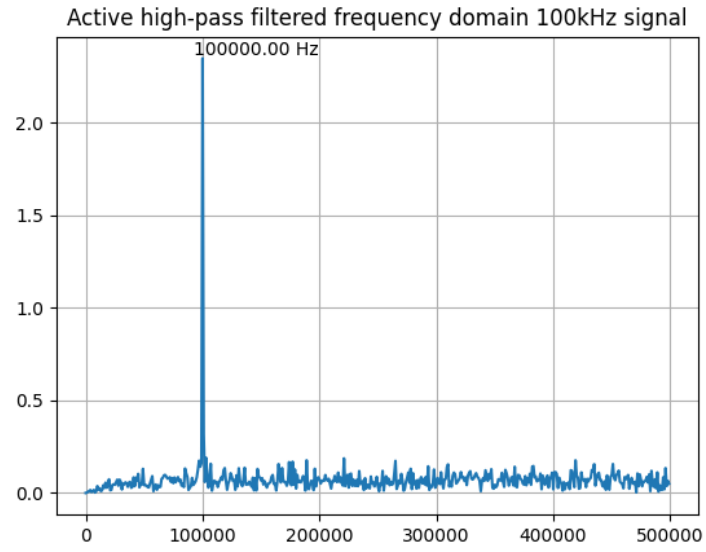


(b) Sinal de 50kHz no domínio da frequência

Sinais Filtrados: Filtro Passa-Alta Ativo



(a) Sinal de 100kHz filtrado



(b) Sinal de 100kHz no domínio da frequência

SNR: Sinal de Saída do Filtro Passa-Alta

$$SNR_{1\text{kHz}} = -26.43\text{dB}$$

$$SNR_{10\text{kHz}} = -6.84\text{dB}$$

$$SNR_{50\text{kHz}} = 2.15\text{dB}$$

$$SNR_{100\text{kHz}} = 3.21\text{dB}$$

Comparação do SNR

f_{sinal}	Sinal de Entrada	Passa-Baixa	Passa-Alta
1kHz	3.19 dB	13.40 dB	-26.43 dB
10kHz	3.19 dB	12.99 dB	-6.84 dB
50kHz	3.19 dB	8.00 dB	2.15 dB
100kHz	3.19 dB	3.04 dB	3.21 dB

Tabela: Comparação do SNR dos sinais de entrada e saída dos filtros

Conclusão

- Verifica-se a importância dos filtros bem dimensionados para obter a redução de ruídos;
- Para um ruído branco e um filtro passa-baixa, observa-se o caráter decrescente da SNR do sinal de saída em função da frequência do sinal de interesse (o inverso para passa-alta);
- Filtros passa-baixa obtiveram melhores resultados devido a distribuição da potência do ruído nas frequências.