



# Seminário Filtros Digitais

Processamento Digital de Sinal

Licenciatura em Engenharia de Telecomunicações e Informática

13 de outubro - 2023/2024

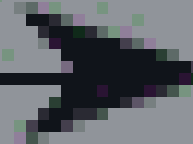
Departamento de Eletrónica Industrial



## AGENDA

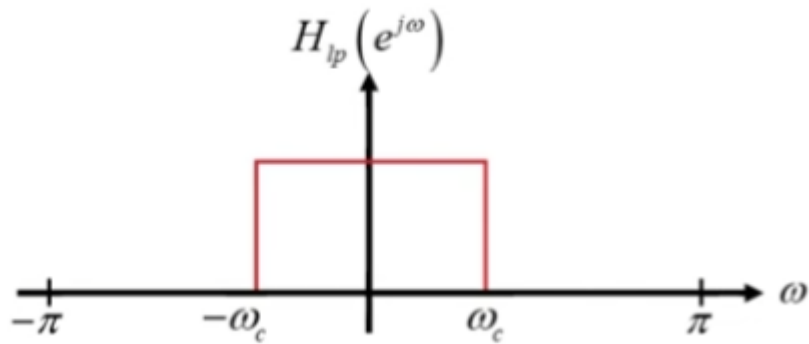
- 01 Filtros
- 02 FIR vs IIR
- 03 Matlab Filter Designer
- 04 Implementação no Arduino

$x[n]$

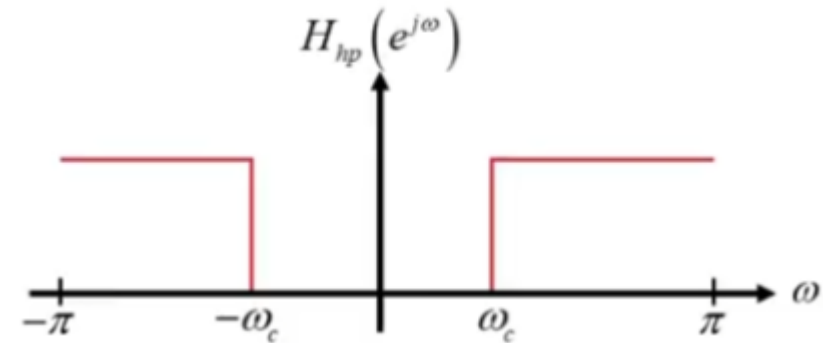


Dis  
Sy

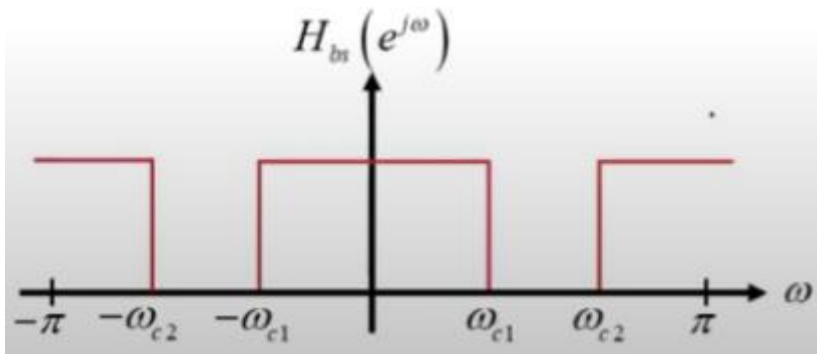
# Filtros



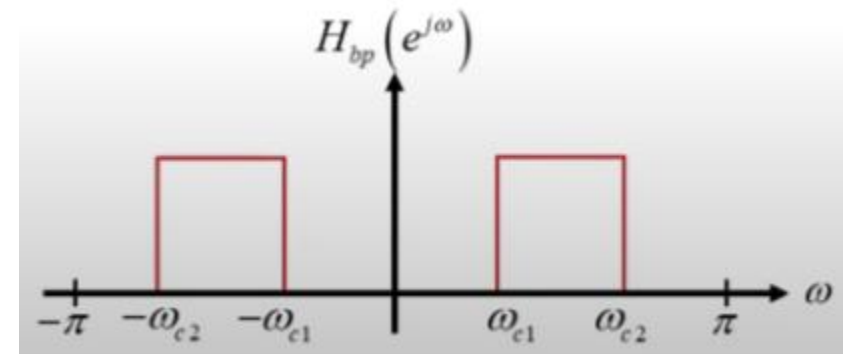
Filtro Passa-Baixo



Filtro Passa-Alto

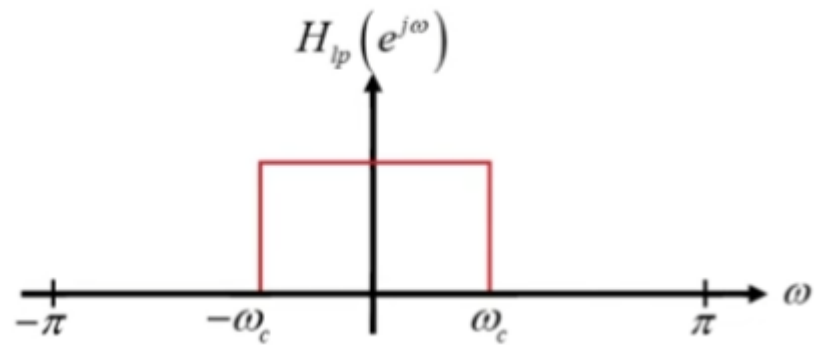


Filtro Rejeita-Banda

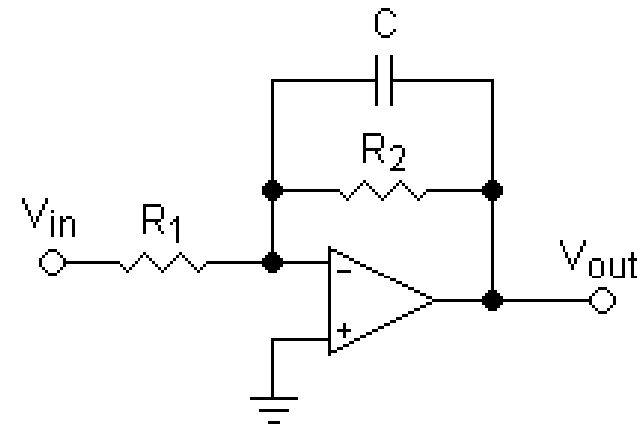
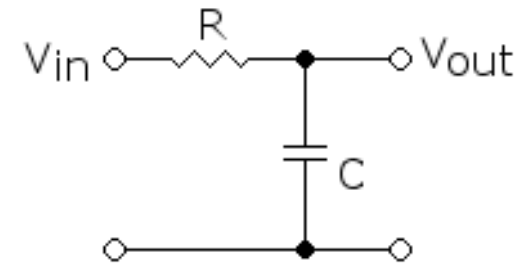


Filtro Passa-Banda

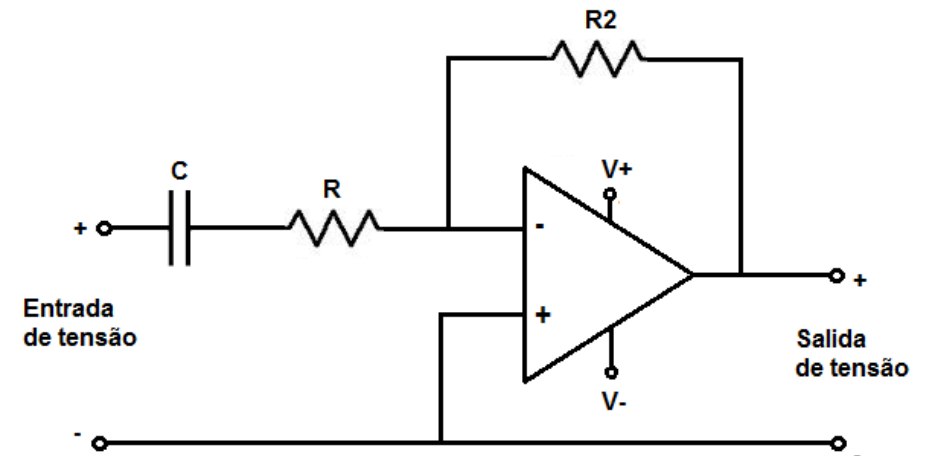
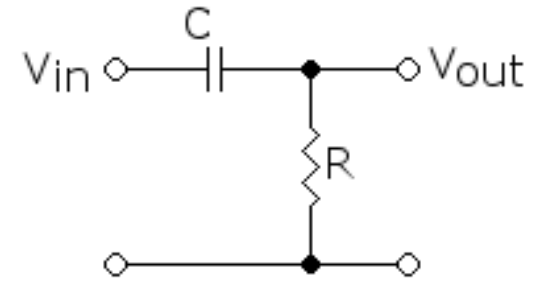
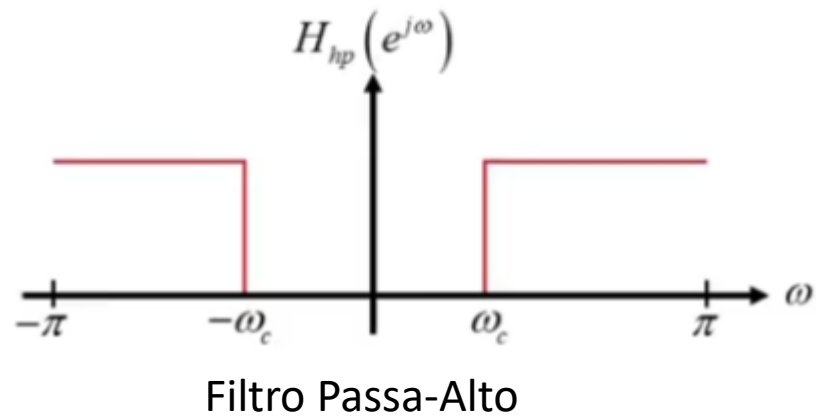
# Filtros



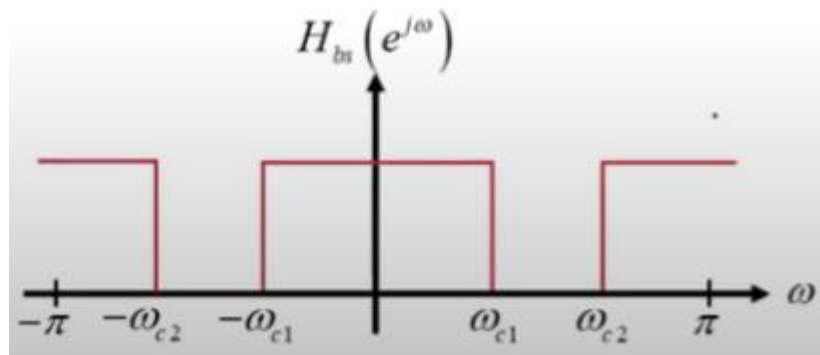
Filtro Passa-Baixo



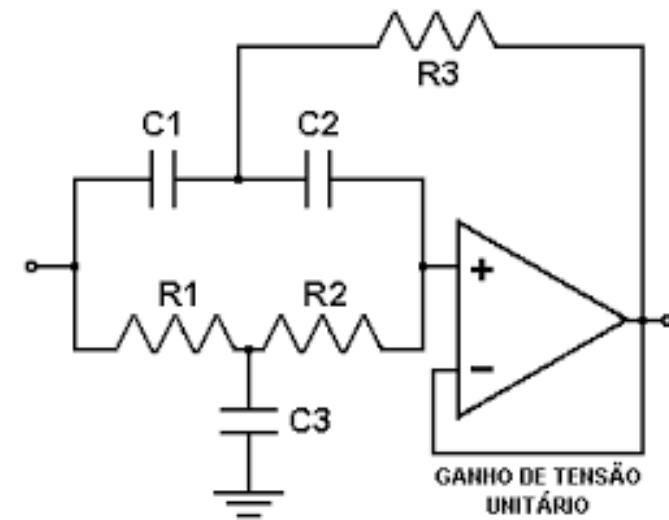
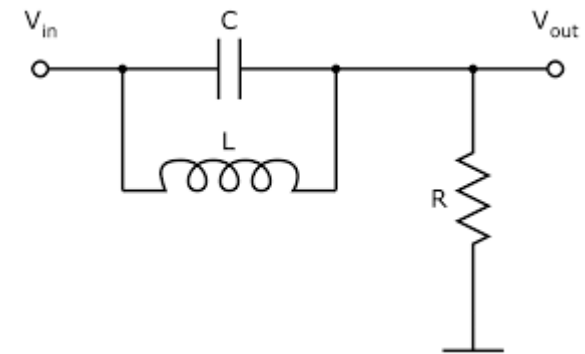
# Filtros



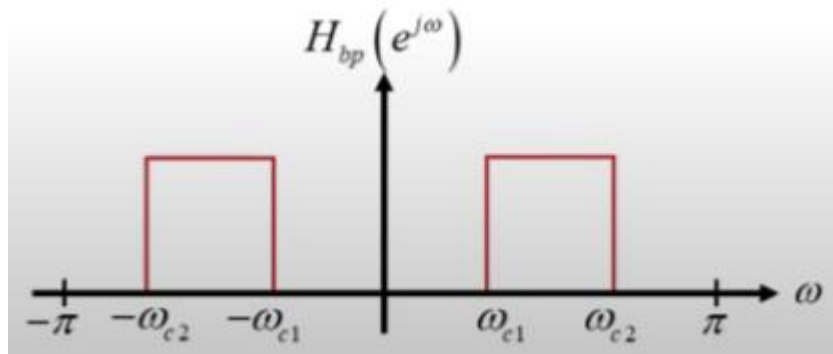
# Filtros



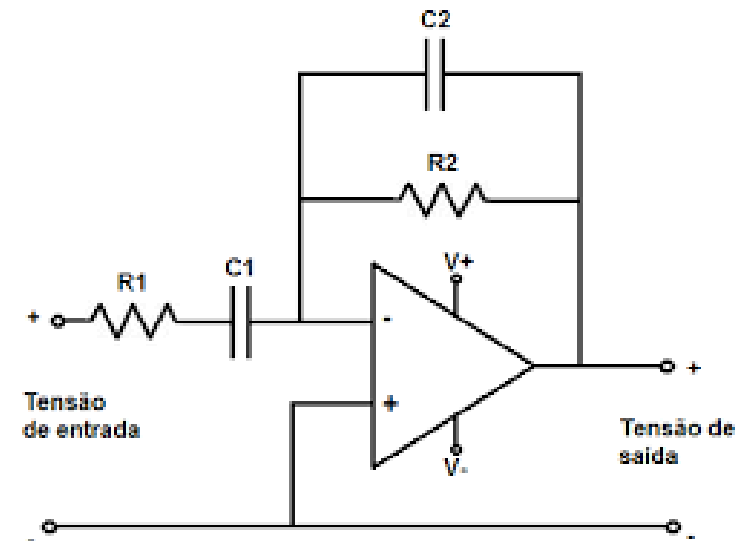
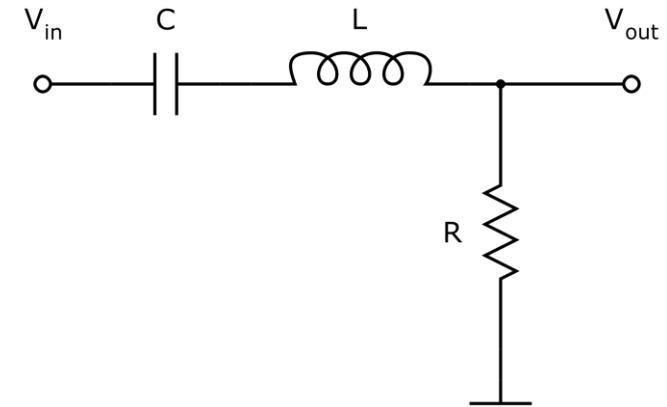
Filtro Rejeita-Banda



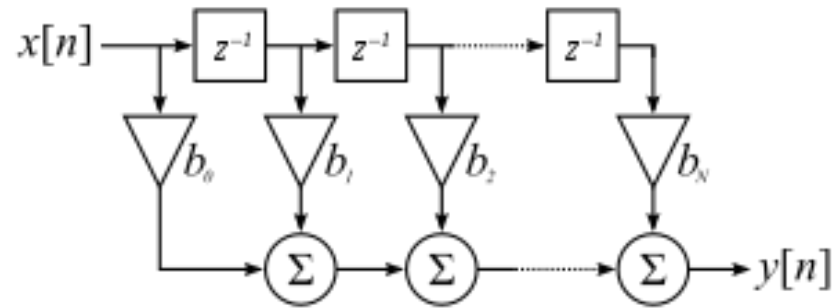
# Filtros



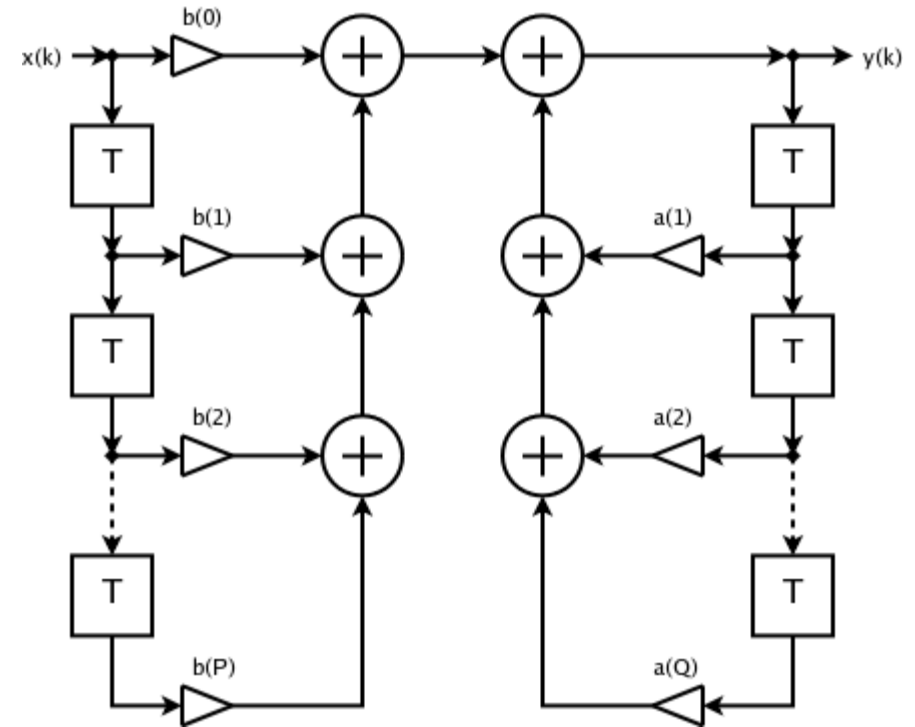
Filtro Passa-Banda



# Filtros FIR & IIR



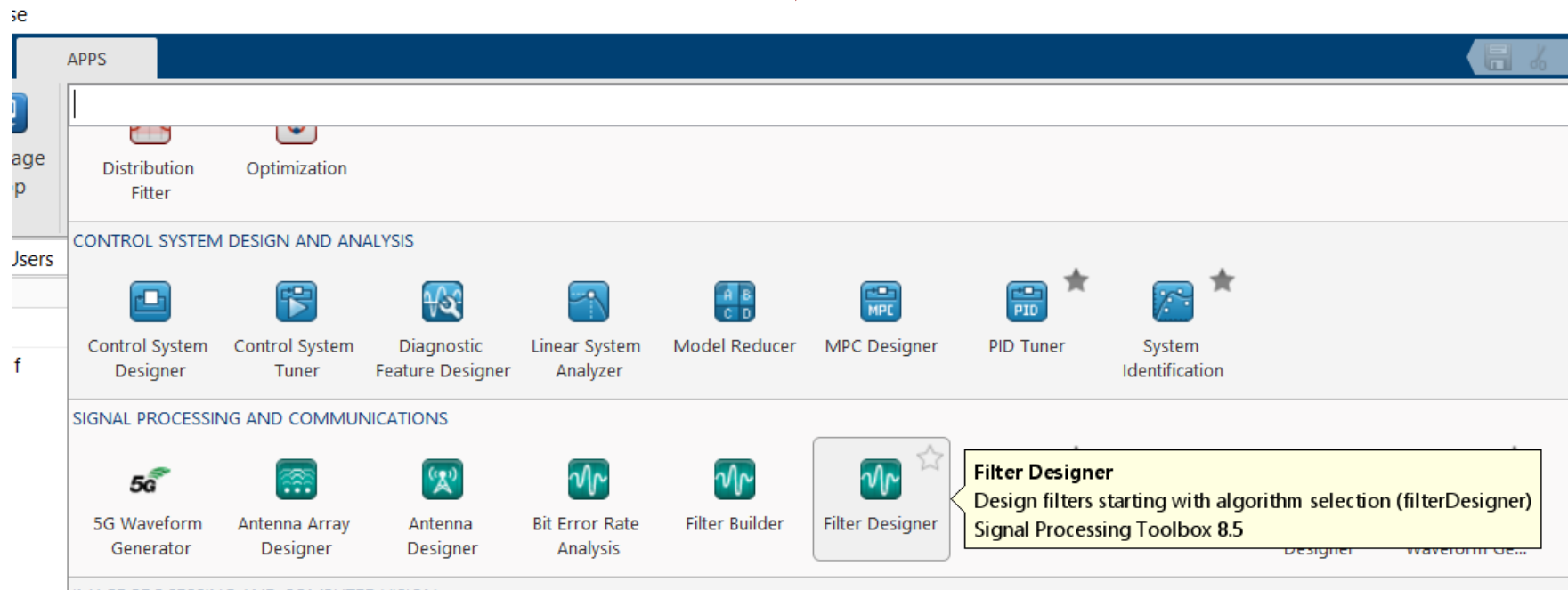
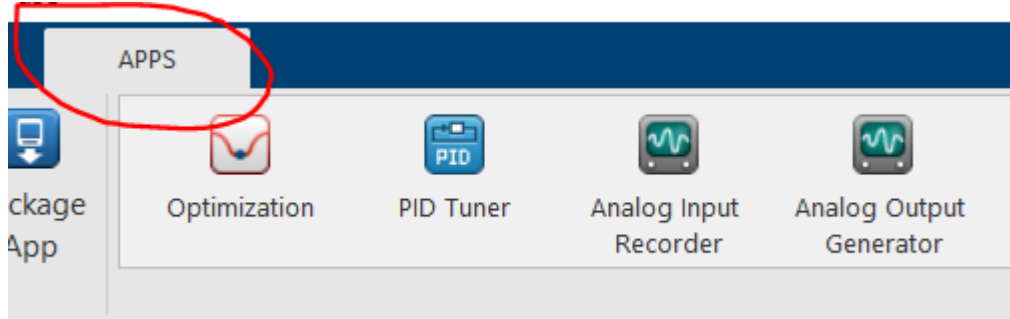
Filtro FIR



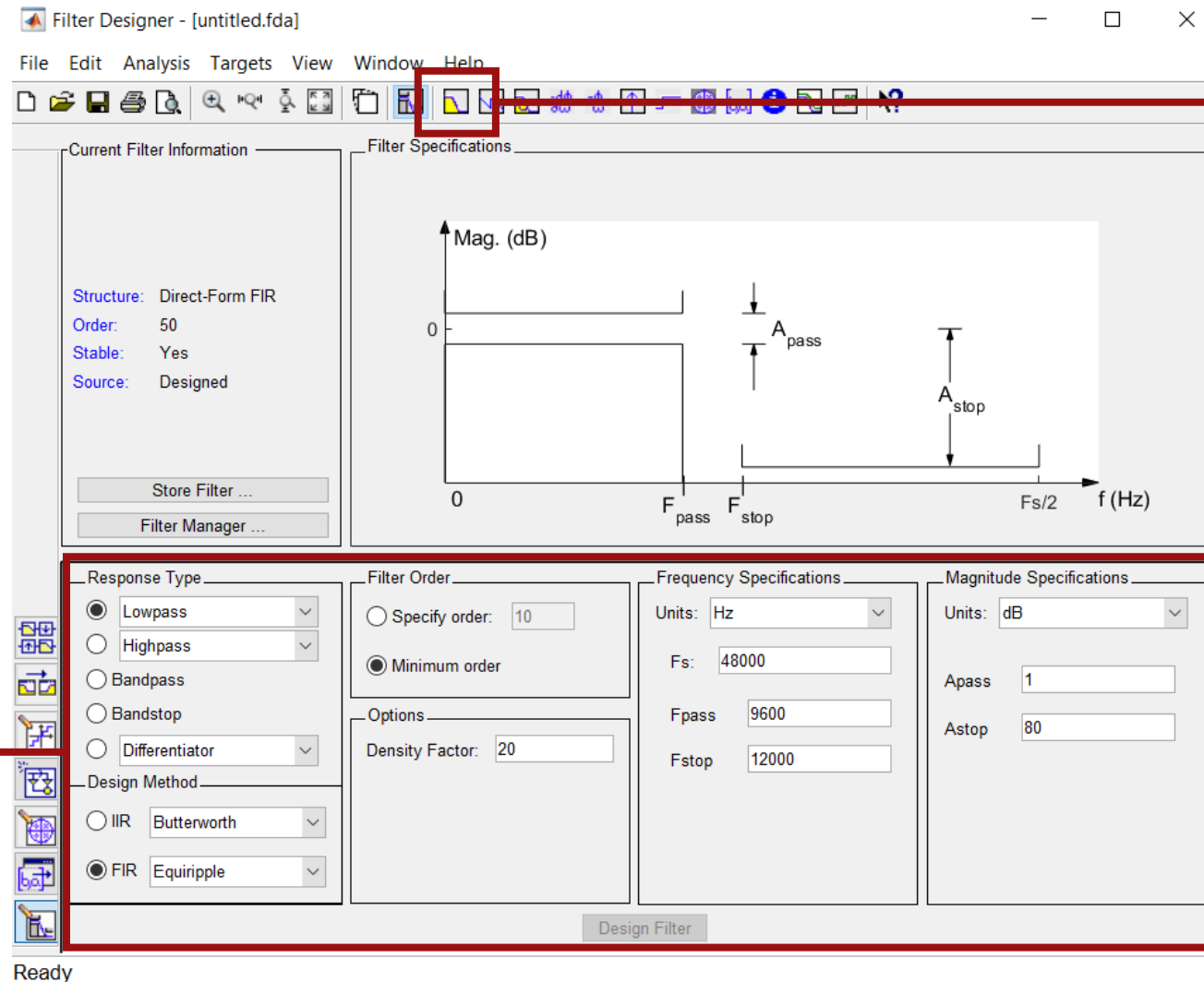
Filtro IIR



# Matlab Filter Designer



# Matlab Filter Designer



Tipo de Resposta  
Método de Design  
Ordem do Filtro  
Freq. Amostragem  
Freq. de corte

Ver a resposta em  
Frequência do Filtro (dBs)

# Matlab Filter Designer



## EXEMPLO 1

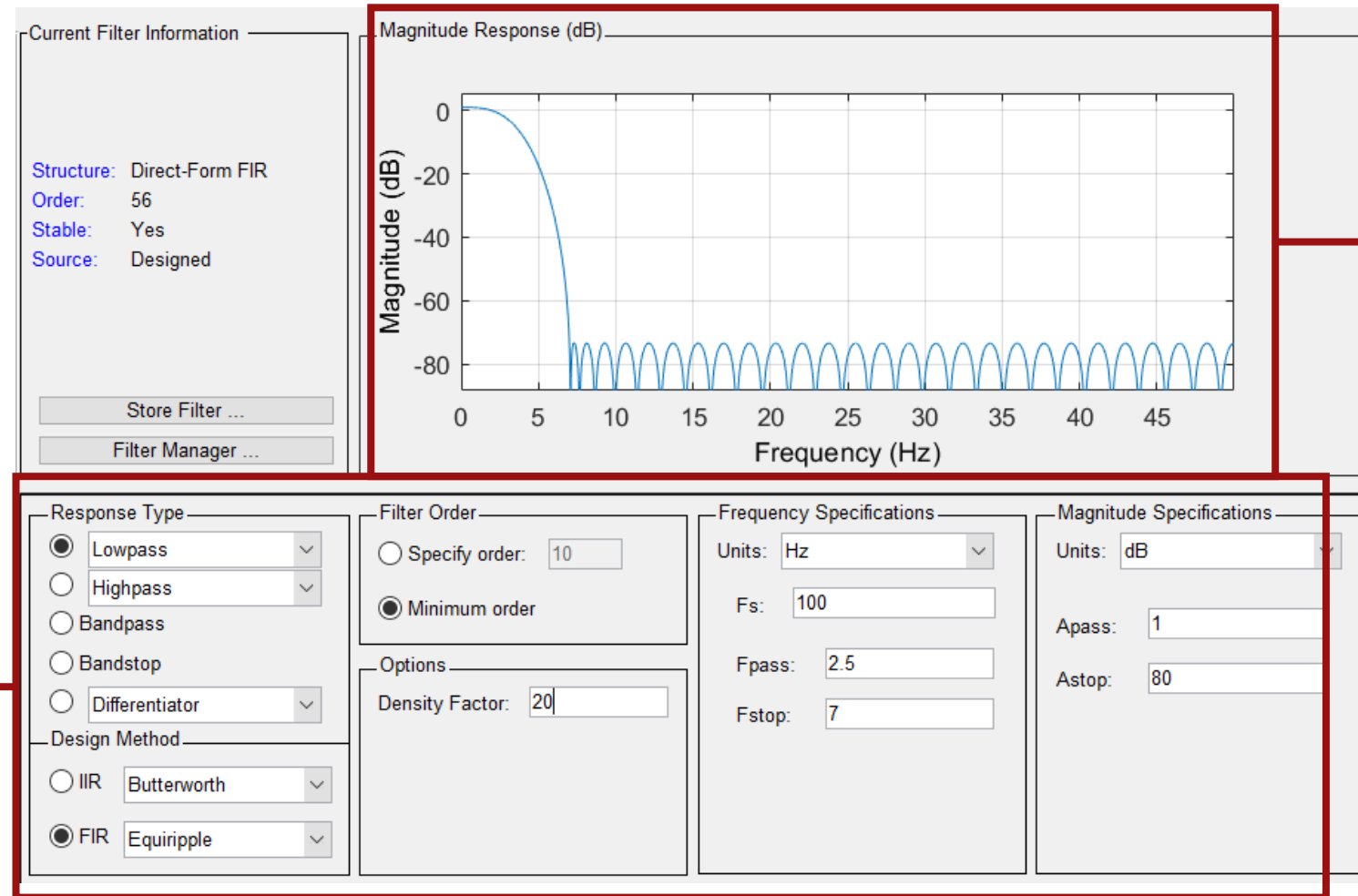
Equiripple (FIR)

Lowpass Filter

Order: 56

$F_c = 2.5\text{Hz}$

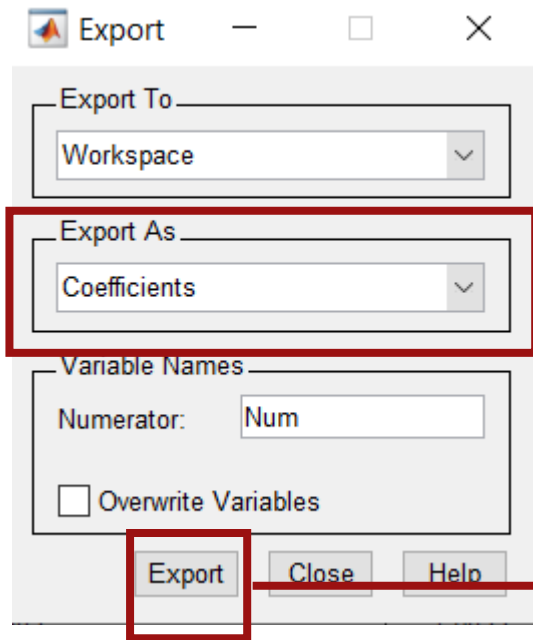
$F_s = 100\text{ Hz}$



$$\pi \Rightarrow 50\text{Hz}$$

Filtro apenas irá passar as baixas frequências

# Matlab Filter Designer



	1	2	3	4	5
1	-2.5680e-04	-4.3857e-04	-7.7119e-04	-0.0012	-0.0018

Exportar os coeficientes para o Workspace

Aplicar diretamente a convolução

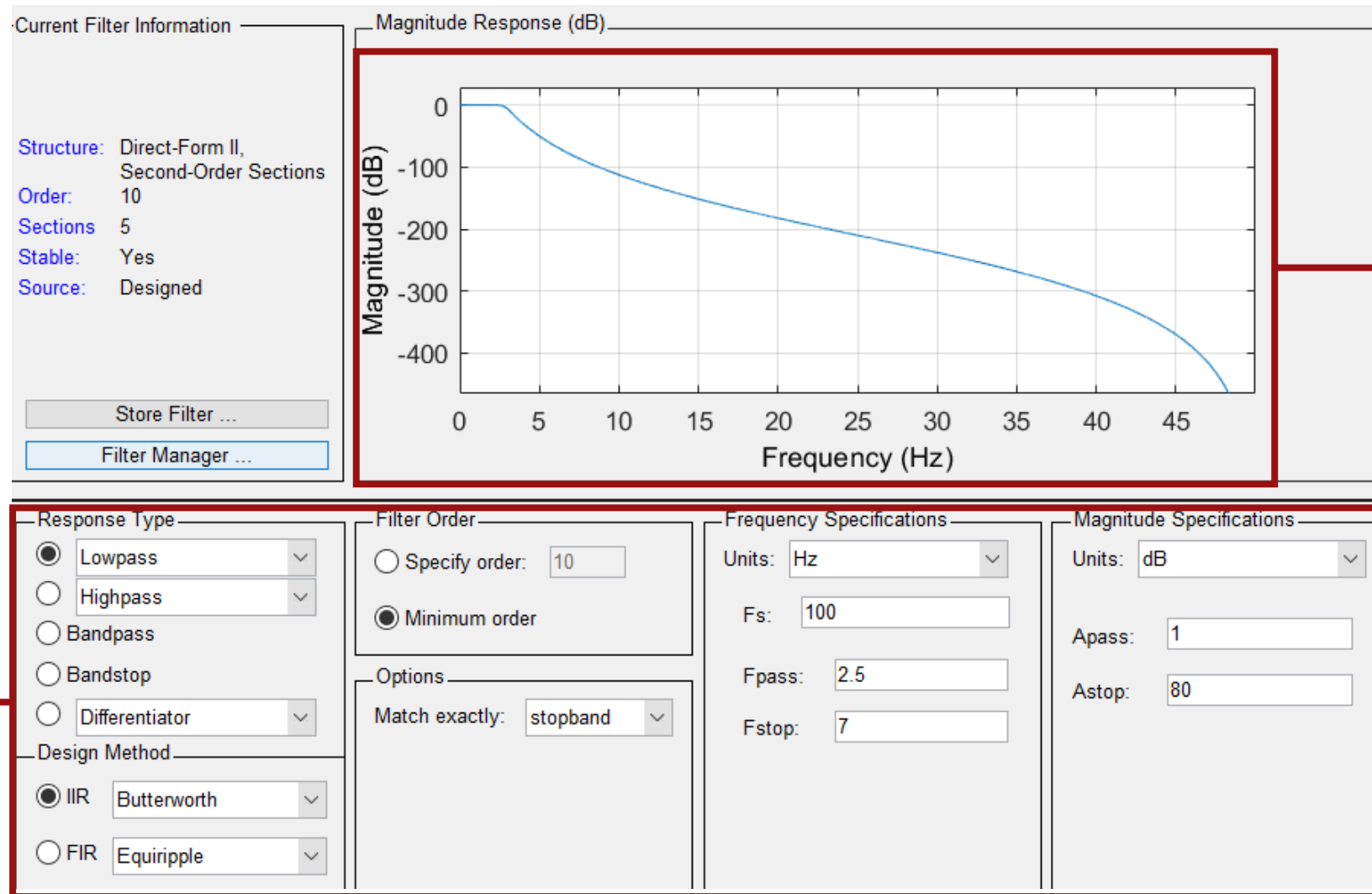
```
coeff = flip(Num);  
for i=length(Num):length(x)  
    y(i) = sum( x(i-length(Num)+1:i) .* coeff' );  
end
```

# Matlab Filter Designer



## EXEMPLO 2

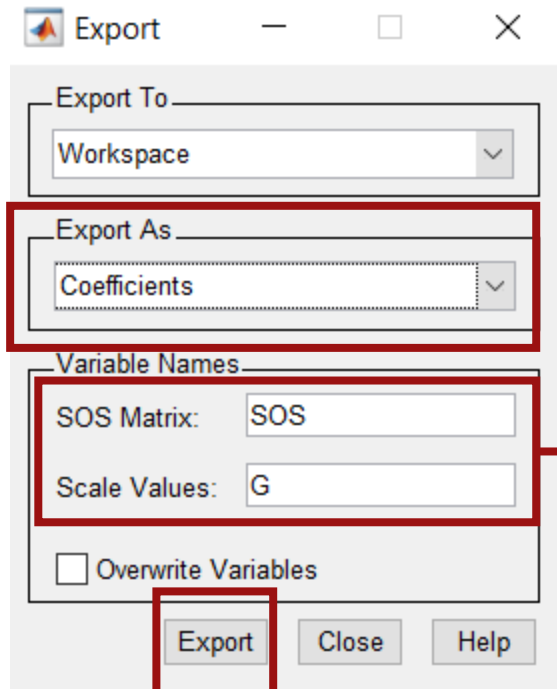
Butterworth (IIR)  
Lowpass Filter  
Order: 10  
 $F_c = 2.5\text{Hz}$   
 $F_s = 100\text{ Hz}$



$\pi \Rightarrow 50\text{Hz}$

Filtro apenas irá passar as  
baixas frequências

# Matlab Filter Designer



Exportar os coeficientes  
para o Workspace

`[b,a] = sos2tf(SOS, G)`

Obter os coeficientes a partir da função `sos2tf` para obter eq. de diferenças

$$a(1)*y(n) + a(2)*y(n-1) + \dots + a(Na+1)*y(n-Na) = \\ b(1)*x(n) + b(2)*x(n-1) + \dots + b(Nb+1)*x(n-Nb)$$

Colocar o  $y[n]$  isolado para obter o sinal de saída do sistema  
Exemplo:

```
>> [b,a]=sos2tf(SOS2)
```

```
b =
```

```
1    2    1
```

```
a =
```

```
1.0000   -0.3695    0.1958
```

```
out(i)= 1*InputSignal(i)+ 2*InputSignal(i-1)+  
1*InputSignal(i-2) + 0.3695*out(i-1) - 0.1958*out(i-2);
```

```
y2 = zeros(size(x));
```

```
for i=length(a):length(x)
```

```
    parte_1 = b(1)*x(i) + b(2)*x(i-1) + b(3)*x(i-2) + b(4)*x(i-3) + b(5)*x(i-4) + b(6)*x(i-5) + b(7)*x(i-6) + b(8)*x(i-7) + b(9)*x(i-8) + b(10)*x(i-9) + b(11)*x(i-10);  
    parte_2 = a(2)*y2(i-1) + a(3)*y2(i-2) + a(4)*y2(i-3) + a(5)*y2(i-4) + a(6)*y2(i-5) + a(7)*y2(i-6) + a(8)*y2(i-7) + a(9)*y2(i-8) + a(10)*y2(i-9) + a(11)*y2(i-10);
```

```
    y2(i) = (parte_1 - parte_2)/a(1);
```

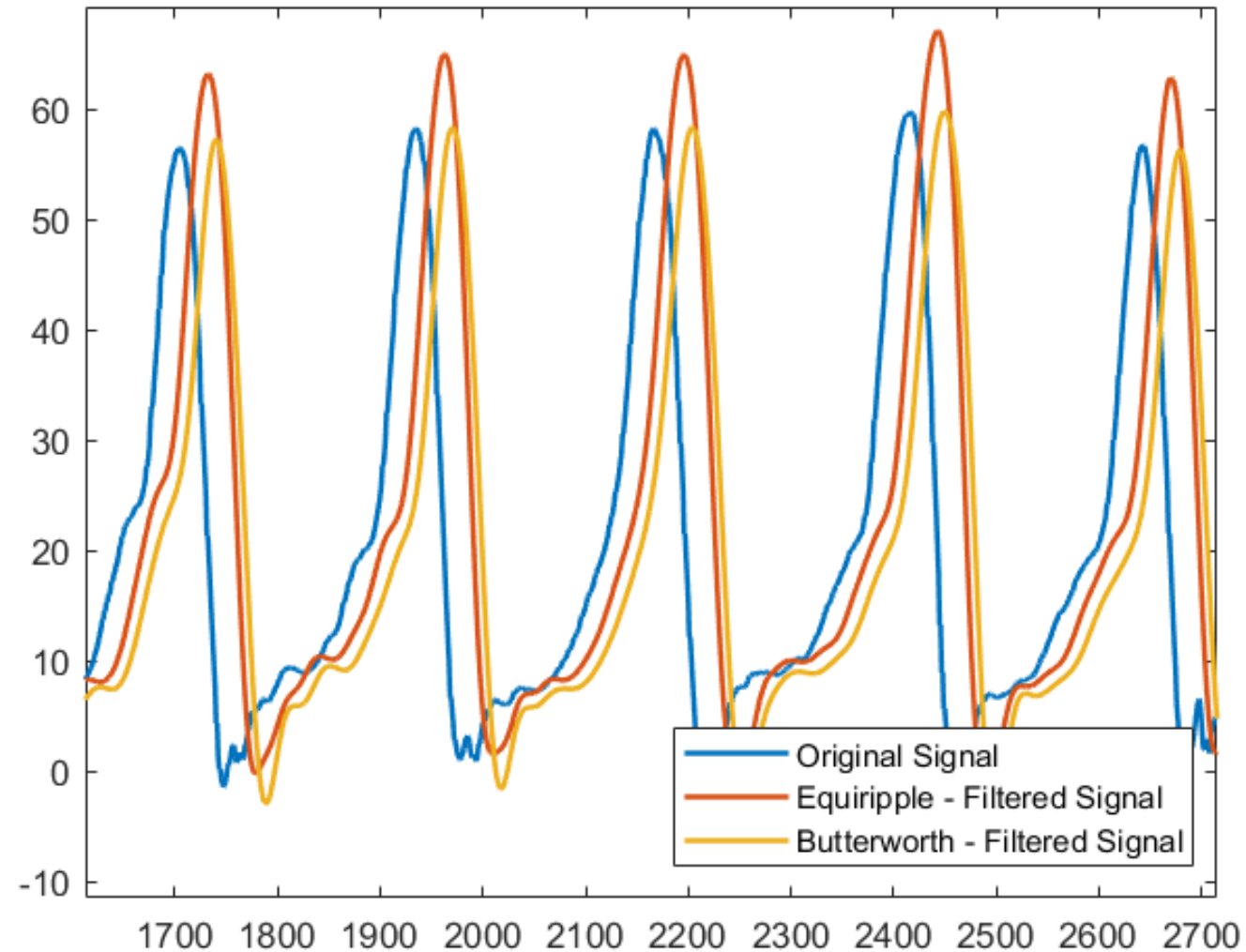
```
end
```

`sos2tf` : 2nd-order sections to transfer function model conversion

# Matlab Filter Designer



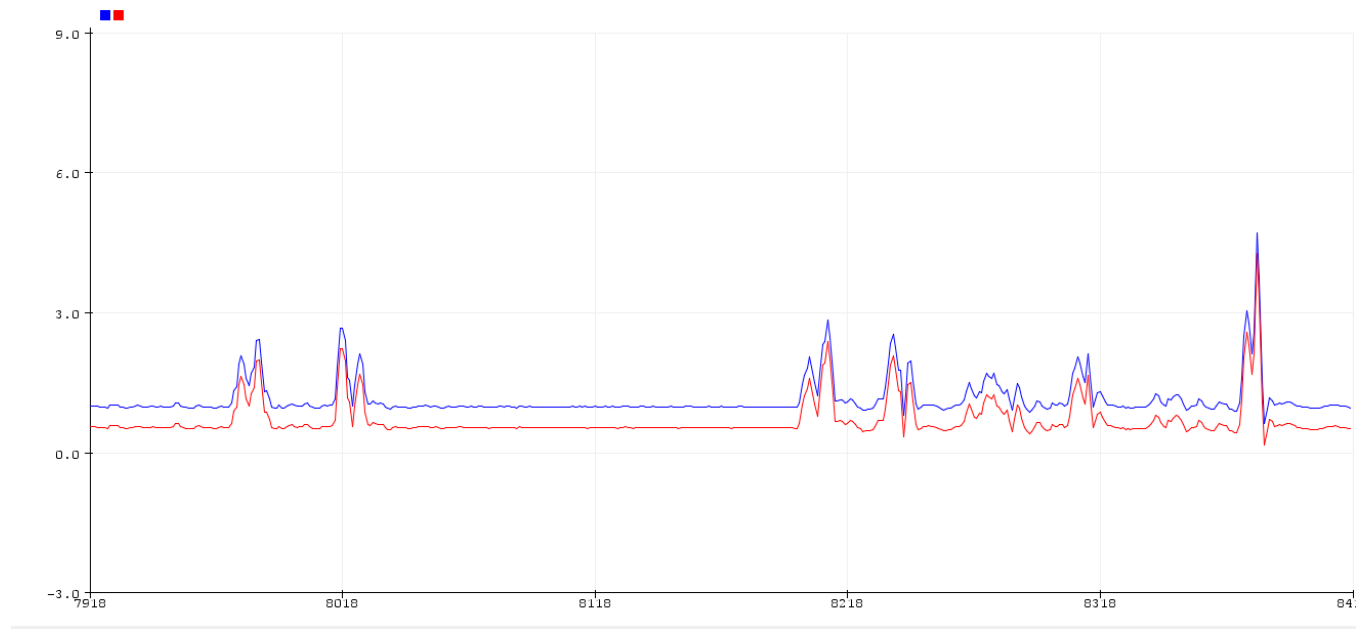
Sinais Filtrados apresentam atraso!



# Arduino UNO



```
if (mpu.update()) {  
  //Obtain sensor data  
  float ax = mpu.getAccX(); float ay = mpu.getAccY(); float az = mpu.getAccZ();  
  x = sqrt(ax*ax + ay*ay + az*az);  
  Serial.print(x, 5); Serial.print(',');  
  
  y = x - x_prev + 0.99995*y_prev;  
  Serial.println(y, 5);  
  
  y_prev = y;  
  x_prev = x;  
}
```



Exemplo de um Filtro Passa-Alto simples



# Primeira Aplicação



Abrir o Matlab e criar um filtro de raiz.

- Experimentar gerar os 4 tipos de filtro no Matlab Filter Designer;
- Criar Código para implementá-los e verificar o seu correto funcionamento;
- Introduzir sinusoides de frequência variada e avaliar a saída (desenhar diagrama de bode experimental);
- Implementar um dos filtros digitais criados em tempo-real no Arduino.

[http://www.biyoklinikder.org/TIPTEKNO20\\_Bildiriler/068.pdf](http://www.biyoklinikder.org/TIPTEKNO20_Bildiriler/068.pdf)

<https://www.mathworks.com/help/signal/ref/sos2tf.html>

<https://www.ling.upenn.edu/courses/ling525/filters1.html>



# Seminário Filtros Digitais

Processamento Digital de Sinal

Licenciatura em Engenharia de Telecomunicações e Informática

13 de outubro - 2023/2024

Departamento de Eletrónica Industrial