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* Dsp project :

<u>IIR Filter :</u> lowpass filter by Butterworth — instead we would use matlab builtin func.

① First we get The function in S-domain and Then apply impulse invariance method

Butterworth
↓
impulse invariance

We need
- $w_p \rightarrow$ passband edge freq.
- $W_s \rightarrow$ Stopband edge frequency
- $A_{max} \rightarrow$ Maximum allowable attenuation in passband
- $A_{min} \rightarrow$ minimum allowable attenuation in stopband

①

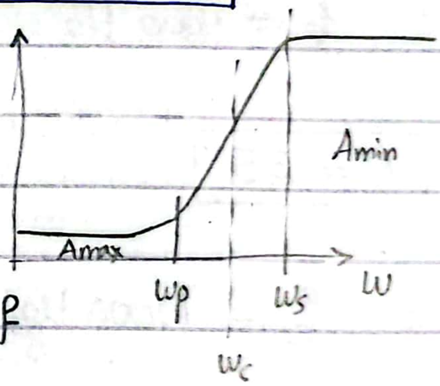
① Using rectangular window: $\boxed{A_{max} = 0.7\ dB \quad A_{min} = 21\ dB}$

at $f_c = 2000\ Hz$

$\therefore W_c = 2000 \times 2\pi$ rad/s

$\therefore W_p = 1500 \times 2\pi$ Rad/s

$\therefore W_s = 2500 \times 2\pi$ rad/s



$$n = \frac{\log\sqrt{\dfrac{10^{0.1A_{min}}-1}{10^{0.1A_{max}}-1}}}{\log\dfrac{W_s}{W_p}} = 6.4317 \simeq 7 \text{ order of T.F}$$

at $f_c = 4000\ Hz$

$W_p = 3500 \times 2\pi$ rad/s

$W_s = 4500 \times 2\pi$ rad/s

$\boxed{n = 13}$ → Not efficient

at $f_c = 10000\ Hz$

$W_p = 9500 \times 2\pi$ rad/s

$W_s = 10500 \times 2\pi$ rad/s

$\boxed{n = 32}$ → Not efficient

② Hamming window : $A_{max} = 0.0194$ dB $A_{min} = 53$ dB

at $f_c = 2000 Hz$

$W_s = 2500 \times 2\pi$ rad/sec $\quad W_p = 1500 \times 2\pi$ rad/sec

$$n = \frac{\log\left(\sqrt{\frac{10^{0.1 A_{min}} - 1}{10^{0.1 A_{max}} - 1}}\right)}{\log\left(\frac{W_s}{W_p}\right)}$$

$\boxed{n = 17.2}$

at $f_c = 4000 Hz$ $\begin{cases} W_p = 3500 \times 2\pi \text{ rad/sec} \\ W_s = 4500 \times 2\pi \text{ rad/sec} \end{cases}$

$\boxed{n = 35}$

at $f_c = 10000 Hz$ $\begin{cases} W_p = 9500 \times 2\pi \text{ rad/s} \\ W_s = 10500 \times 2\pi \text{ rad/s} \end{cases}$ $\boxed{n = 87.98} \Rightarrow 88$

③ Black_man $A_{max} = 0.0017$ dB $A_{min} = 74$ dB

at $f_c = 2000 Hz$ $\quad \underline{n = 25}$

at $f_c = 4000 Hz$ $\quad \underline{n = 50}$

at $f_c = 10000 Hz$ $\quad \boxed{n = 124.319}$

The design of These orders will be very complex as we have seen The order is very high that's because of The narrow transition region we might want to increase the transition region abit

We will choose arbitrary values for w_p, w_s

① Rectangular window:

at $f_c = 2000$ Hz $\begin{cases} w_p = 1800 \times 2\pi \text{ rad/s} \\ w_s = 3500 \times 2\pi \text{ rad/s} \end{cases}$ $n = 5$

at $f_c = 4000$ Hz $\begin{cases} w_p = 3800 \times 2\pi \text{ rad/s} \\ w_s = 5500 \times 2\pi \text{ rad/s} \end{cases}$ $n = 9$

at $f_c = 10000$ Hz $\begin{cases} w_p = 9800 \times 2\pi \text{ rad/s} \\ w_s = 11500 \times 2\pi \text{ rad/s} \end{cases}$ $n = 201$

② Hamming

at $f_c = 2000$ Hz $n = 8$

at $f_c = 4000$ Hz $n = 15$

at $f_c = 10000$ Hz $n = 32$

$f_p = f_c - 500;$
$f_s = f_c + 2500;$

③ Blackman,

at $f_c = 2000$ Hz $n = 12$

at $f_c = 4000$ Hz $n = 21$

at $f_c = 10000$ Hz $n = 467$

$f_p = f_c - 500;$
$f_s = f_c + 2500;$

Program Design

IIR

* We saw that to achieve the low transition region with max., and min attenuation required by the windows it would take us a large func. with many (high order)

Previously designed

Rectang. Hamming Blackman

choose one of

$f_c = 2000, 4000, 10000$ Hz

choose $f_s = ?$

Design filter

Your own IIR filter with your specs

Put your own A_{max}, A_{min}

func. for

$$n = \frac{\log\sqrt{\frac{10^{0.1A_{min}}-1}{10^{0.1A_{max}}-1}}}{\log\left(\frac{f_s}{f_p}\right)}$$

choose $f_c = ?$

choose $f_s = ?$

Design filter

Plot filter

Plot previous and after ⇒ sound

compare both