IIR DIGITAL FILTER DESIGN
BY
BILINEAR TRANSFORMATION. MATLAB APPLICATION

Exercise 6.

Function, operators, special characters	Description of function, operators and special characters
[B,A] = butter(N,Wn)	Function designs an Nth order lowpass digital Butterworth filter and returns the filter coefficients in length N+1 vectors B and A.
[N, Wn] = buttord(Wp, Ws, Rp, Rs)	Function returns the order N of the lowest order digital Butterworth filter that loses no more than Rp dB in the passband and has at least Rs dB of attenuation in the stopband.
[B,A] = cheby1(N,R,Wn)	Function designs an Nth order lowpass digital Chebyshev filter with R decibels of peak-to-peak ripple in the passband. CHEBY1 returns the filter coefficients in length N+1 vectors B and A.
[N, Wn] = cheb1ord(Wp, Ws, Rp, Rs)	Function returns the order N of the lowest order digital Chebyshev Type I filter that loses no more than Rp dB in the passband and has at least Rs dB of attenuation in the stopband.
[B,A] = cheby2(N,R,Wn)	Function designs an Nth order lowpass digital Chebyshev filter with the stopband ripple R decibels down and stopband edge frequency Wn. CHEBY2 returns the filter coefficients in length N+1 vectors B and A.
[N, Wn] = cheb2ord(Wp, Ws, Rp, Rs)	Function returns the order N of the lowest order digital Chebyshev Type II filter that loses no more than Rp dB in the passband and has at least Rs dB of attenuation in the stopband.
[B,A] = ellip(N,Rp,Rs,Wn)	Function designs an Nth order lowpass digital elliptic filter with Rp decibels of peak-to-peak ripple and a minimum stopband attenuation of Rs decibels. ELLIP returns the filter coefficients in length N+1 vectors B and A.
[N, Wn] = ellipord(Wp, Ws, Rp, Rs)	Function returns the order N of the lowest order digital elliptic filter that loses no more than Rp dB in the passband and has at least Rs dB of attenuation in the stopband.

Example 1.

Design a low-pass filter with pass-band cut off frequency $f_1 = 20\,kHz$ and stop-band cut off frequency $f_2 = 30\,kHz$. Frequency sampling is $f_S = 160\,kHz$.

Example 2.

Design a band-pass filter with pass-band cut off frequencies $f_1 = 20\,kHz$ and $f_2 = 40\,kHz$. The width of transition bands is $5\,kHz$. Frequency sampling is $f_S = 160\,kHz$.

Example 3.

Design a stop-band filter filter with pass-band cut off frequencies $f_1 = 20\,kHz$ and $f_2 = 40\,kHz$. The width of transition bands is $5\,kHz$. Frequency sampling is $f_S = 160\,kHz$.

Comments

1. *For the solution of the above given examples, the m-files butter.m, cheby1.m, cheby2.m and ellip.m for the IIR filter design. For the designed filters compare frequency response (magnitude response, phase response, group delay) of the different kind filters of the same order as well as the different kind filters of the different order.*
2. *For the designed filter plot zero-pole plot.*
3. *For the designed filter compute and plot an approximation of impulse response.*

Example 4. Filtering

Let $x_1(t) = 2\cos 2\pi f_1 t$, $x_2(t) = 2\cos 2\pi f_2 t$, $f_1 = 15\,kHz$, $f_2 = 45\,kHz$, $y(t) = x_1(t)x_2(t)$ and $f_0 = 200\,kHz$ is sampling frequency. By using a suitable FIR filter extract $y(t)$ from signal $z(t) = y(t) + n(t)$, where $n(t)$ is zero-mean Gaussian noise with $\sigma_n^2 = 2$. For signal $z(t)$ as well as for the signal obtained by filtering $z(t)$ evaluate signal-to-noise ratio.
