Design and Simulation of IIR Filter under Graphical User Interface

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***Abstract*-A novel method to simulate the IIR filter based on GUI(Graphic User Interface) is introduced in this paper. This method not only depended on Matlab code, but also made use of controls which generate a GUI. All the operations have been done by GUI. This paper took bilinear transformation method to realize IIR filter for example to design digital low-pass, high-pass and band-pass filters. The simulation results show that the design based on GUI is convenient, fast, intuitive and flexible. In the meantime, it offered a clue and method for the design of digital filter.**

Keywords-GUI, IIR, Digital Filter, Simulation

I. INTRODUCTION

IIR filter plays an important role in digital signal processing, comparing with analogy filter, it has many merits: stability, strong reliability, without voltage floating and noise problem. Besides, the poles of transfer function of IIR filter can be in any place of unit circle, it is convenient to get higher selectivity by using lower filter order, which only needs less memory space and creates more efficiency. What's more, the design of IIR filter depends on the result of analogy filter, so there are many valid formulas to be applied. To some extent, workload can be saved as well.

The simulation of this IIR filter was done by Matlab language which has such merits as high programmable efficiency, simple and straightforward instruction and visualized data. At present, simulation realization of IIR filter only depends on Matlab code, which unavoidably brought about deficiency in repeating, extension and interaction between user and computer. So a novel method to simulate IIR filter based on GUI (Graphic User Interface) was proposed in this paper. This method not only depended on Matlab code, but also it made full use of merits of GUI: convenience, intuition and good interaction between user and computer.

II. THE DESIGN OF IIR WITH BILINEAR TRANSFORMATION

Bilinear transformation is nonlinear frequency compression method: Compress the frequency range between $-\pi/T$ and π/T, then use formula $Z=e^{sT}$ to convert it to Z plane. Presume transfer function of analog filter is $H(s)$, $s=j\Omega$, after compressing, $H(s)$ is expressed with $H(s_1)$, $s_1=j\Omega_1$, here, frequency compression can be realized by tangent transformation, the formula as follows:

$$\Omega=\frac{2}{T}\tan(\frac{1}{2}\Omega_1 T) \tag{1}$$

Obviously, $\Omega_1\in(-\frac{\pi}{T},\frac{\pi}{T})$, $\Omega\in(-\infty,\infty)$, consequently, the transformation from S plane to S_1 plane is finished, so

$$s=\frac{2}{T}th(\frac{1}{2}\Omega_1 T)=\frac{2}{T}\times\frac{1-e^{s_1T}}{1+e^{s_1T}} \tag{2}$$

Finally, by formula $Z=e^{s_1T}$, return to Z plane, then,

$$s=\frac{2}{T}\times\frac{1-Z^{-1}}{1+Z^{-1}} \tag{3}$$

$$Z=\frac{\frac{2}{T}+s}{\frac{2}{T}-s} \tag{4}$$

Formula (3) and formula (4) is called bilinear transformation. The design of IIR is to obtain its coefficient by its performance index with $ellip$ function in signal processing toolbox of Matlab. The amplitude-frequency characteristics curve can be obtained by $freqz$ function. The concrete function of three IIR filter as follows:

(1)low-pass filter function: $[b,a]=ellip(N,R_P,R_S,\omega)$, where N is filter order, R_P is passband minimum attenuation, R_S is stopband maximum attenuation, ω is

normalized cut-off frequency, $0<\omega<1$, b and a are filter coefficient.

(2) high-pass filter function: $[b,a]=ellip(N,R_P,R_S,\omega,'high')$, where N is filter order, R_P is passband minimum attenuation, R_S is stopband maximum attenuation, ω is normalized cut-off frequency, $0<\omega<1$, $high$ means that the type of filter is high-pass filter. b and a are filter coefficient.

(3) band-pass filter function: $[b,a]=ellip(N,R_P,R_S,[\omega_1 \quad \omega_2])$, where N is filter order, ω is normalized cut-off frequency, $\omega=[\omega_1 \quad \omega_2]$, $0<\omega<1$, ω_1 and ω_2 is respectively upper cut-off frequency and lower cut-off frequency of band-pass filter. b and a are coefficient of filter.

III. THE REALIZATION OF IIR FILTER WITH MATLAB GUI

A. *the Merits of Matlab GUI*

GUI is communication platform between user and computer. By using GUI, user can conveniently communicate with Matlab program and control program. Matalb offers ample GUI design instructions which make the realization of GUI more convenient, intuitive and flexible.

B. *GUI construction of IIR filter*

There are 21 controls in this GUI: 8 “static text” and 8 “edit”, the content of 8 “static text” is respectively frequency1, frequency2, frequency3, t, sample fre, cutoffre1 and cutoffre2(if filter is high-pass filter, cutoff fre1 is its cut-off frequency; if filter is low-pass filter, cutoff fre2 is its cut-off frequency; if filter is band-pass filter, cutoff fre1 and cutoff fre2 is its upper cut-off frequency and lower cut-off frequency); the content of 8“edit” is edited parameters which correspond to 8“static text”; “one popupmenu” which contains three items: highpass, lowpass and bandpass. When user input parameter in “edit”, click correspondent item of popupmenu, its amplitude-frequency characteristics curve can be obtained; 4“pushbutton”: Draw1, Draw2, Close and Clear. Click Draw1, time domain and frequency domain waves of original signal can be obtained; click Draw 2, time domain and frequency domain waves of the filtered signal can be obtained; click Close, close GUI; click Clear, clear all the waves of GUI. The concrete example as follows:

C. *GUI example of IIR filter*

Mixed signal $x=\sin(2\pi f_1 t)+\sin(2\pi f_2 t)+\sin(2\pi f_3 t)$, $f_1<f_2<f_3$,design low-pass, high-pass and band-pass filters, demands as follows: select f_1 with low-pass filter; select f_3 with high-pass filter; select f_2 with band-pass filter.

Altogether 21 controls were produced by $uicontrol$ of GUI instruction, $uicontrol$ has an important property: $callback$. when clicking the control which has this property, the property value(Matlab instruction) was recalled and the control performed its function. After the GUI was established, a M file named Signal Analyser was created, run this M file, a empty GUI is shown as figure1.

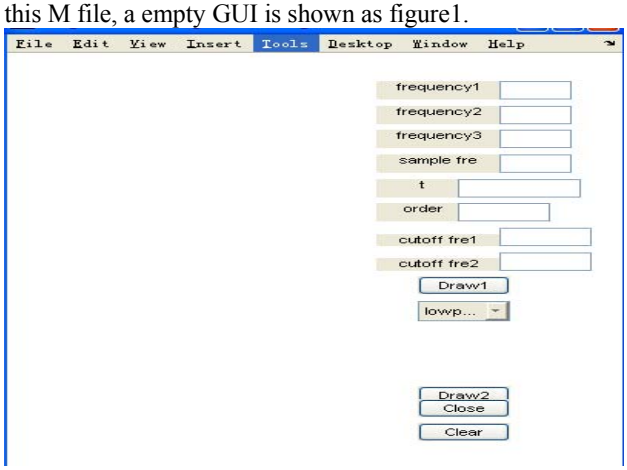

Figure 1. Empty GUI of IIR filter

Presume frequency of mixed signal x is respectively 200Hz, 300Hz and 400Hz, then according to Nequist rule, sample frequency 1000Hz is ok. Now select 300Hz signal with bandpass filter.

Input correspondent parameters in blank “edit”of figure1, click Draw1, time domain wave and frequency domain wave of original signal can be obtained, see figure2.

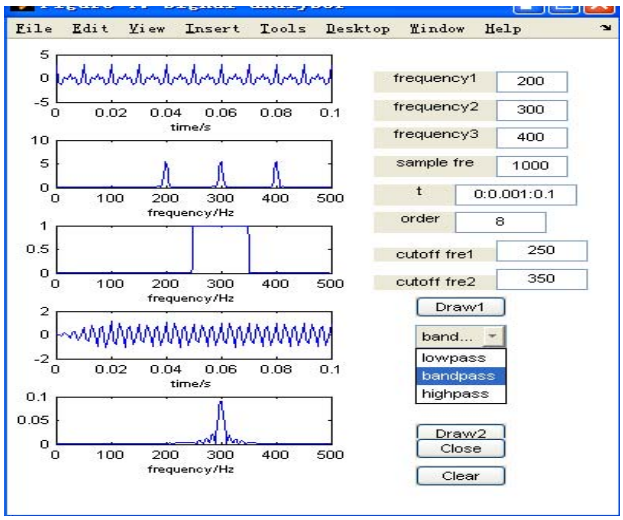

Figure 2. GUI of band-pass filter

In figure2, the second wave is frequency domain wave of mixed signal, three frequency components can be seen clearly. Click bandpass item of popupmenu, amplitude-frequency characteristics can be obtained, it is the third wave of figure2. Click Draw2, time domain wave and

frequency-domain of the filtered signal can be obtained, they are the last two waves of figure2. From amplitude-frequency wave, 200Hz and 400Hz signal are diminished, but 300Hz signal is selected out. Click clear, clear all the waves. The cleared GUI are shown as figure3.

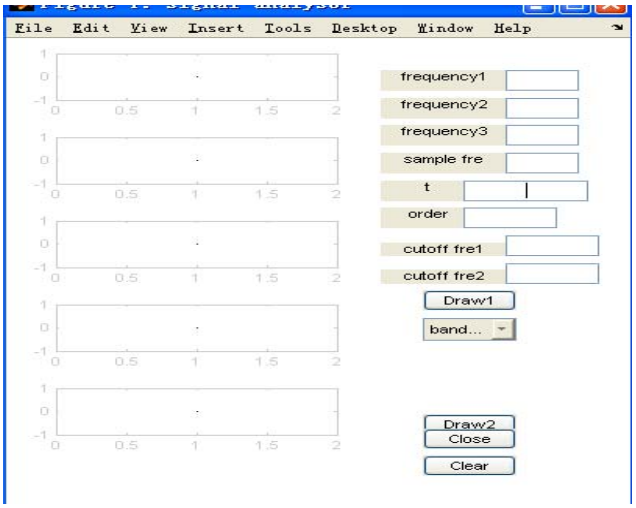

Figure 3. Cleared GUI of filter

If cut-off frequency1 is 350Hz, cut-off frequency2 is blank, click Draw1, highpass item of popupmenu and Draw2, the new waves are shown as figure4.

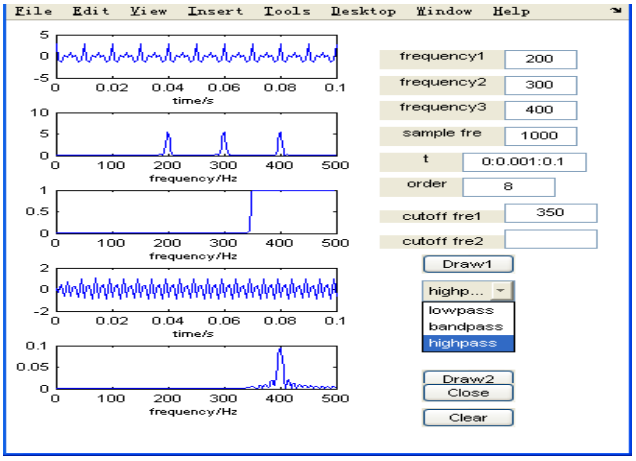

Figure 4. GUI of high-pass filter

If cut-off frequency2 is 250Hz, cut-off frequency1 is blank, click Draw1, lowpass item of popupmenu and Draw2, the new waves are also can be obtained. Given the same theory, waves aren't offered any more. Click close, close GUI.

IV. CONCLUSION

The GUI realization of IIR filter was offered in the form of example in this paper. In GUI, input and modification of data is convenient, output result is fast and intuitive. Repeated recall of M file which only depends on Matlab code is avoided, and workload is lightened.

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