

Research on IIR Band-Stop Filter Based on STM32

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Abstract: This paper describes an IIR band-stop filter developed based on the STM32F103 microcontroller. The design details the process of setting filter parameters in MATLAB and how these parameters and original signal data are input into the microcontroller. The research work is divided into three parts: (1) generating filter parameters using MATLAB, (2) applying them on the STM32F103 module, and (3) outputting signal data via serial port. First, filter coefficients are generated through MATLAB and used as input for IIR filtering processing in the STM32 function; then the original data is processed using the IIR filtering function from the DSP library, with computation results stored in an array; finally, the filtered signal data is output through the serial port. Experiments demonstrate satisfactory filtering performance, with the IIR filter showing significant advantages in efficiency, transition band width, and computational complexity.

Keywords: IIR filter; microcontroller; filter parameters; signal processing

1. INTRODUCTION

In modern technological development, digital signal processing technology has become increasingly important. Filters can be classified by function into low-pass, band-pass, high-pass, and band-stop types, and by design approach into FIR and IIR types [1]. This paper focuses on the design process of IIR band-stop filters, discussing their theoretical foundations, design procedures, and implementation techniques.

Filter parameters are generated through MATLAB software and imported into the STM32 microcontroller, which processes signals and sends data to the host computer via serial port for analysis. This paper uses STM32 as the experimental platform to verify the practicality of the IIR band-stop filter algorithm. The implementation of IIR filters on STM32 can use existing functions from the DSP library or custom functions [2]. This paper aims to deepen the understanding of IIR band-stop filter working principles and provide reference for related technical practices.

2. IIR BAND-STOP FILTER OVERVIEW

2.1 Definition and Characteristics of IIR Filters

IIR (Infinite Impulse Response) filters have the following characteristics: (1) the system function $H(z)$ has poles within a finite z -plane; (2) the current system output is related to previous inputs and outputs, with a structure containing feedback loops, conforming to a recursive structure; (3) the unit impulse response $h(n)$ is an infinite sequence [3].

2.2 Basic Structure of IIR Filters

The basic structures of IIR filters include direct form I, direct form II, cascade form, and parallel form. Direct form II reduces the number of memory elements compared to direct form I, simplifying the computation. Cascade form facilitates zero-pole adjustment with smaller computational errors; parallel form has independent subsystem errors that do not interfere with each other.

2.3 Introduction to Band-Stop Filters

Band-stop filters are used to attenuate signals within a specific frequency range in the input signal, also known as notch filters. They can pass frequencies above and below the band but attenuate frequencies within the band. They are commonly used for signal denoising and interference

suppression [4], with the classic application being the elimination of power line interference. Band-stop filters can be implemented using IIR or FIR approaches, with common methods including Butterworth, Chebyshev, and elliptic designs.

2.4 Implementation of IIR Filters

IIR filter implementation can be divided into direct implementation, indirect implementation, and system function implementation. Direct implementation follows the difference equation; indirect implementation uses z -transform; system function implementation is based on transfer function design, typically using tools like MATLAB [5]. Unlike FIR filters, IIR filters have limitations such as phase response variation and potential instability, requiring selection of the most suitable implementation method.

3. SYSTEM DESIGN

This design uses MATLAB to generate the superimposed signal to be filtered and IIR band-stop filter coefficients, calls the STM32 DSP library, applies relevant filtering functions, stores signal data and coefficients in arrays, compiles and downloads, then prints filtered waveform data through the serial port. Waveforms are then plotted and spectral analysis is performed using MATLAB and Excel, comparing MATLAB results with ARM official library results, as shown in Figure 1.



Figure 1. Overall design of IIR band-stop filter

3.1 Hardware Design

The hardware design includes two parts: peripheral components of the STM32F103 microcontroller (power circuit, reset circuit, clock circuit, GPIO pin design) and USB-to-TTL circuit design. The STM32F103C8T6 is a low-power, high-performance 32-bit ARM Cortex-M3 microcontroller with 64KB flash memory and 20KB SRAM, operating at up to 72MHz, featuring rich communication interfaces and peripherals.

3.2 Software Design

The software design involves configuring filter coefficients and generating input signals using MATLAB, as well as writing application programs using STM32CubeIDE. The ARM official direct form I IIR library supports four data types: Q7, Q15, Q31, and floating point. The direct form I IIR filter is implemented using second-order Biquad cascading, where higher-order filters use cascaded structure, and an 8th-order filter requires four second-order Biquad sections.

3.3 Filter Parameter Design

Filter parameters are designed using MATLAB's filterDesigner tool. The sampling rate is 1Kbps, a Butterworth band-stop filter is designed using direct form I, with stopband cutoff frequencies of 100Hz and 325Hz, passband attenuation of 3dB, stopband minimum attenuation of 70dB, 1024 samples collected, and filter order set to 4. The system default generates direct form II, which is converted to direct form I, yielding two sets of second-order IIR filter coefficients as shown in Table 1. In practical applications, a1 and a2 need to be negated.

Table 1. Filter coefficients

	Group 1	Group 2
b0	1	1
b1	-0.614	-0.614
b2	1	1
a0	1	1

a1	-1.145	0.474
a2	0.502	0.353

Each second-order filter corresponds to a gain, and the filtered data needs to be multiplied by the gain coefficient. Both Group 1 and Group 2 have gain coefficients of 0.583. The IIR filter function used in this paper is `arm_biquad_cascade_df1_f32`, which can design IIR low-pass, high-pass, band-pass, and band-stop filters.

4. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Filtering Effect

The original signal consists of superimposed 50Hz and 200Hz signals. Through the STM32F103 microcontroller utilizing its built-in DSP library and IIR filtering algorithm, the 200Hz signal component was successfully filtered. After setting the band-stop filter cutoff frequencies to 100Hz and 325Hz, the 200Hz signal component was effectively eliminated.

4.2 Spectrum Analysis

The STM32 processing data was stored in a MATLAB array, and FFT analysis was performed to obtain spectra before and after filtering. The band-stop filter was designed to eliminate the 200Hz component while preserving the 50Hz component. After filtering, the 200Hz frequency was suppressed, its peak disappeared, and only the 50Hz peak remained, verifying the frequency-selective characteristics of the filter.

4.3 Result Comparison

The data processed by the `arm_biquad_cascade_df1_f32` function was output through the serial port. Waveform diagrams were plotted using MATLAB to compare MATLAB computation results with ARM official library function results. The two results were basically consistent, verifying the correctness of the IIR filter function implementation on STM32.

4.4 Frequency Response of IIR Band-Stop Filter

The input signal consists of 11 groups of sine waves with different frequencies but identical amplitudes. After STM32 processing, waveform data was displayed through the serial port, yielding amplitude data as shown in Table 2. When signals of different frequencies pass through the band-stop filter, signals near the center frequency of 200Hz are attenuated, and the output signal mainly retains low-frequency and high-frequency components. The frequency response curve is similar to that of an ideal band-stop filter, showing significant attenuation at the cutoff frequencies.

Table 2. Measured amplitude-frequency values

Frequency (Hz)	Input Amplitude (V)	Output Amplitude (V)	Attenuation (dB)
10	5	4.575	-0.7716
30	5	4.567	-0.7868
50	5	4.511	-0.8939
80	5	4.048	-1.8346

100	5	3.235	-3.7819
150	5	0.703	-17.0403
200	5	0.001	-73.9794
300	5	2.227	-7.0250
350	5	3.927	-2.0982
400	5	4.204	-1.5061
450	5	4.571	-0.7792

5. CONCLUSION

This study described the design and development process of an IIR band-stop filter implemented using the STM32 microcontroller. The paper explained the working principles and characteristics of IIR filters, discussed band-stop filter design methods, and described the specific development process of integrating hardware and software, covering key aspects including filter coefficient determination, signal generation and processing, and spectral analysis. Experimental results verified that the STM32-based IIR band-stop filter achieved the expected filtering performance.

Future work can be optimized in several directions: upgrading to a digital filter supporting online parameter adjustment to enhance flexibility; considering higher-performance processors to meet real-time processing requirements; and improving processor bit width or adopting other techniques to enhance filter coefficient precision.

6. ACKNOWLEDGMENTS

The authors would like to thank the experts who have contributed to the development of this work.

7. REFERENCES

- [1] Jiang E, Zhou J, Zou F, et al. Design of FIR digital filter comprehensive experiment[J]. Journal of Qufu Normal University (Natural Science Edition), 2023, 49(01): 64-68.
- [2] Wei H. Research on head-mounted heart rate detection technology related to energy efficiency[D]. Nanjing: Nanjing University of Posts and Telecommunications, 2023.
- [3] Li D, Zhao L, Deng J, et al. Research on improved single sensor control strategy for semi-active suspension[J]. Noise and Vibration Control, 2023, 43(05): 232-238.
- [4] Qiu W, Ding S. Comparison and recognition classification of preprocessing methods for spectral signals of animal and vegetable oils based on filters[J]. Food and Fermentation Industries, 2023, 49(08): 281-288.
- [5] Tang J, Zou B. Design of portable track circuit online monitoring recorder[J]. Railway Operation Technology, 2023, 29(04): 17-21.