

# Allpass lattice structure based second order digital IIR notch filter for removing DC and very low frequencies

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*Abstract*— In this paper, an allpass lattice structure based second order notch filter with notch at dc is designed. The filter perfectly removes the dc and the specified very low frequencies. It can be designed for a very sharp transition band thereby eliminating frequencies close to DC. The filter is simple to implement and the number of multipliers required is equal to one. For the purpose of illustration, the filter is designed to meet a cutoff frequency of 1 Hz for a sampling frequency 800 Hz and applied to remove the baseline wander in ECG signals.

**Keywords:** allpass filter, baseline wander, ECG signal

## 1. INTRODUCTION

In many signal processing applications, there is a need to remove a single frequency component from a signal while leaving rest of the spectrum unaltered. Conventional IIR/FIR digital filter design methods yield a filter of very high order to meet these specifications. In particular, medical signal processing of ECG signals, there is a need to eliminate the dc and the base line wander (0.05Hz). The recommendations of the American Heart Association state that the frequency components above 0.05Hz should not be removed [1]. Many techniques are described in the references [3] – [5] for removing the base line wander in ECG signals. The technique in reference [3] is based on the estimation of base line wander whereas in reference [4] and those in references [5] are based on the design of FIR digital filters. The FIR digital filtering methods suffer from the disadvantages of complex hardware implementation and long computation time due to the large number of multiplications. The order of the filter of [5] designed for this purpose is 26.

In order to overcome these problems, a simple design of notch filter which makes use of a second –order all pass filter is proposed. The design approach is similar to that in reference [2], where notch filters based on allpass is discussed. Hardware implementation of the proposed filter is simple and requires one multiplier only. As an example the proposed filter is designed for a cutoff frequency of 1 Hz for sampling frequency of 800 Hz. A table giving the allpass filter coefficients for cutoff frequencies of 0.5Hz and 2Hz is also presented.

## 2. Proposed allpass based digital IIR Notch filter

In this section, a second order all pass lattice structure based digital IIR notch filter design for removing dc and specified low frequency is presented. The transfer function of the all pass based notch filter is

$$H(z) = \frac{1}{2} [1 + A(z)] \quad (1)$$

Where,

$$A(z) = \frac{a_1 + a_2 z^{-1} + z^{-2}}{1 + a_2 z^{-1} + a_1 z^{-2}} \quad (2)$$

Fig.1 shows the lattice structure for the implementation of  $A(z)$  of equation (2).The transfer function of the lattice structure of fig.1 is

$$A(z) = \frac{k_2 + k_1(1 + k_2)z^{-1} + z^{-2}}{1 + k_1(1 + k_2)z^{-1} + k_2 z^{-2}} \quad (3)$$

The constants  $k_1$  and  $k_2$  are related to the digital notch frequency  $\omega_0$  and the 3-dB notch bandwidth  $\Omega$  as [2]

$$k_1 = -\cos \omega_0 \quad (4)$$

$$k_2 = \frac{1 - \tan(\Omega/2)}{1 + \tan(\Omega/2)} \quad (5)$$

In the present design, we have  $\omega_0 = 0$  and  $\Omega / 2 =$  cut off frequency in radians. The lattice structures are known for their excellent sensitivity and stability characteristics.

### 2.1 Design Example

Sampling frequency = 800 Hz =  $2\pi$  radians.

Cutoff frequency = 1 Hz = 0.0079 radians.

From Equations (4) and (5), we have

$$k_1 = -\cos \omega_0 = -1 \quad (6)$$

$$k_2 = 0.9922 \quad (7)$$

Fig.(2) shows the frequency response of the designed notch filter. It can be seen that the filter has a sharp transition band. Fig.3 and Fig.4, show the original ECG signal with the base line drift and the filtered signal respectively. It can be seen that the drift is effectively removed.

### 3. Conclusion

This paper presents a method for designing an allpass lattice structure based second-order digital IIR notch filter for removing DC and very low frequencies. This filter is effectively used to remove baseline wandering of ECG signal. This notch filter can be realized with one multiplier constant only and thus is simple to implement. The designed allpass lattice structure based notch filter is stable and possesses very low sensitivity.

TABLE- I

ALL PASS FILTER COEFFICIENTS

Cutoff frequency	$k_1$	$k_2$
2Hz	-1	0.9844
0.05Hz	-1	0.9996

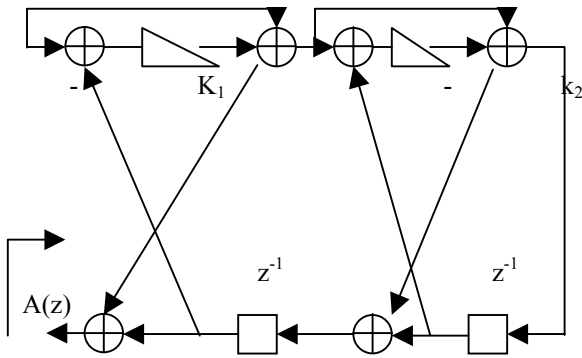


Fig.1.Lattice structure of the All pass filter

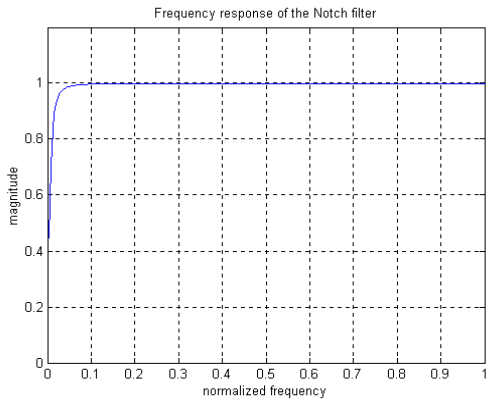


Fig.2 Frequency Response

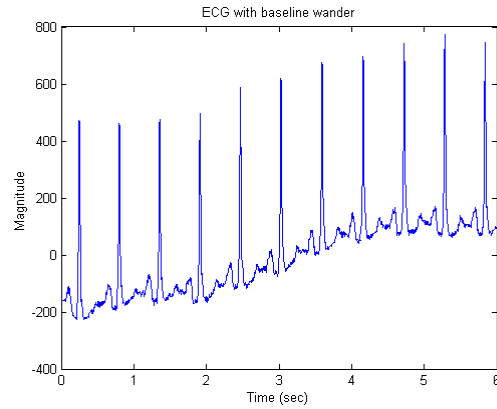


Fig.3. Original signal with baseline drift.

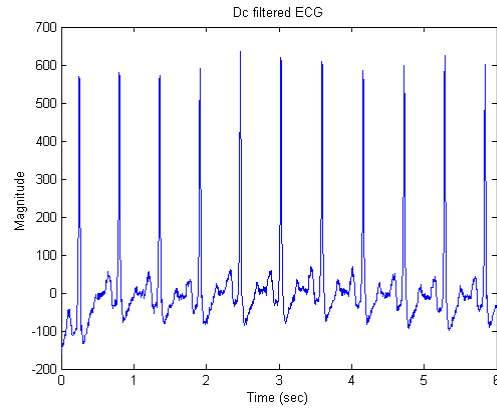


Fig.4.Filtered Signal

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