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CFOA Based Band Pass Filter Using AD844 IC for ECG Signal

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Abstract— In this paper band pass filter has been proposed to design the filter of ECG signal with a very high speed current conveyor IC AD844. ECG signal are ranges from 0.1-100 Hz, sometimes reaching up to 1 kHz Therefore the proposed design provides a satisfactory results at output on a very low frequency from 0.5 to 150 Hz with an amplitude of 5 mV.

In this paper the output results are obtained by help of simulation software NI-Multisim and Ultiboard design for PCB layout.

Keywords— Band Pass filter, AD844 IC, ECG signal, NI-Multisim, Ultiboard

I INTRODUCTION

In biomedical field, filters designed with very low frequency range have a wider range of applications like EEG and ECG Signals. The (Electrocardiogram) ECG signal are ranges from 0.1-100 Hz. Before further digital process, amplification and pre-filtering of ECG signal are necessary. Therefore, to design the filter of ECG signal on a very low frequency it is necessary to select proper component value with high speed op-amp ICs. Many research has been carried out over the decade to design the filter for ECG signal [1-3]. In [1] a 1 volt rail-to-rail input range amplifier has been proposed. The proposed amplifier was useful to implement a low pass filter for biomedical signal applications. In [2] The proposed design used an analog front end design (AFE) that was used for Electrocardiogram (ECG) signal acquisition using an instrumentation amplifier (IA), a DC blocking high pass filter, a high order anti-aliasing low pass filter, and a successive approximation register analog-to-digital converter (SAR-ADC). In [3] the patent was granted in Oct. 21, 2014 on the design that was based on the low frequency filter for biomedical applications to scale down the pole frequency while accomplishing a 5-bit reduction in the cut off frequency. An exemplary second-order low pass filter was designed and simulated.

Because the bandwidth of ECG signals are ranges from 0.1 to 100 Hz, sometimes reaching up to 1 kHz therefore it is needed to select the signal at the particular frequency range and attenuate the signal outside the range. For this purpose, ECG signals required a low pass filter and high pass filter also. The low pass filter passes a low frequency signals only while a high pass filter passes a high frequency signals only. To select the low pass and high pass frequencies, band pass filter select the particular band of frequency signals between low cut off frequency and high cut off frequency. Therefore, in this paper the band pass filter design has been proposed using a AD844IC on a very low frequency range of 0.5 to 150 Hz for ECG signal. The frequency can be varied from 0.5 to 150 Hz by simply changing the value of resistor R (potentiometer).

II. INTRODUCTION TO ECG MEASUREMENT SYSTEM

ECG signal: The electrocardiograph (ECG) must be able to detect not only extremely weak signals ranging from 0.5 mV to 5.0 mV, but also a DC component of up to ±300 mV (resulting from the electrode-skin contact) and a common-mode component of up to 1.5 V, which results from the potential between the electrodes and the ground. The useful bandwidth of an ECG signal depends on the application and can range from 0.5-100 Hz, sometimes reaching up to 1 kHz [4].

The ECG system mainly consists of four stages:

The first stage is a transducer. It convert ECG signal into electrical voltage and uses AgCl electrode. The voltage is in the range of 1 mV ~ 5 mV. The second stage is an instrumentation amplifier, which has a very high CMRR (90dB) and high gain (1000), with power supply of +5V and -5V. The third stage is uses an Opto-Coupler to isolate the Instrumentation amplifier and output. The last stage is a bandpass filter of frequency range from 0.5 Hz to 150 Hz. The band pass filter is designed by cascading a high pass filter and low-pass filter [4].

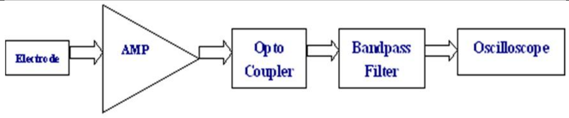

Fig.1: Functional blocks of the ECG system

Source: https://www.jove.com/science education/10473/acquisition-and-analysis-of-an-ecg-electrocardiography-signal

III. AD844 IC

The AD844 is a high speed monolithic operational amplifier fabricated using the Analog Devices, Inc., junction isolated complementary bipolar (CB) process. It combines high bandwidth and very fast large signal response with excellent dc performance. Although optimized for use in current-to-voltage applications and as an inverting mode amplifier, it is also suitable for use in many noninverting applications. The AD844 can be used in place of traditional op amps, but its current feedback architecture results in much better ac performance, high linearity, and an exceptionally clean pulse response. This type of op amp provides a closed-loop bandwidth that is determined primarily by the feedback resistor and is almost independent of the closed-loop gain. The AD844 is free from the slew rate limitations inherent in traditional op amps and other current-feedback op amps. Peak output rate of change can be over 2000 V/μs for a full 20 V output step. Settling time is typically 100 ns to 0.1%, and essentially independent of gain. The AD844 can drive 50 Ω loads to ±2.5 V with low distortion and is short-circuit protected to 80 mA [5].

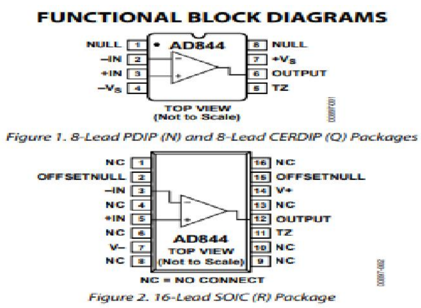

Fig.2: Pin diagram of AD844 IC
Source: https://www.analog.com/media/en/technical-documentation/data-sheets/AD844.pdf

IV BAND PASS FILTERS

Band pass filter is used to select the particular band of frequencies between two cut-off frequencies f_H and f_L and reject the frequencies outside the band.

This filter is designed by cascading a high pass filter and low-pass filter. This filter is depends on the value of Q. Q means quality factor. Higher the value of Q means more selective is the filter. When the value of Q is less than 10 then the filter is called wide band pass filter. In fig. Resistors R_2 and R_1 are used to set the voltage gain. Resistors R and capacitor C are used for filter. In this paper the band pass filter is designed by choosing a cut-off frequencies f_L and f_L from 0.5 -150 Hz with an amplitude of 5mV. The center frequency is 8.66 Hz.

In general, components of the signal of interest will reside in the 0.67 to 40-Hz bandwidth for standard ECGs and up to 300 Hz to 1 kHz for pacemaker detection [6].

To design the band pass filter, it is necessary to select the two cut off frequencies. Therefore to design the band pass filter for ECG signal, in this paper we will select a high cut-off frequency f_H = 150 Hz and f_L = 0.5 Hz

1. To find the center frequency of band pass filter, following formula is used:

f_C = ___ = $\sqrt{0.5 \times 150}$ = 8.66 Hz

2. To find the bandwidth (BW), following formula is used:

BW = f_H-f_L= 149.5

3. To find the value of Q, following formula is used:

Q = — = — =0.05

4. To find the value of R using the following formula:

f_C=1/2πRC or R=1/2πf_C and choose the value of capacitor C≤1μF = .06 μF

R=1/2πf_C = 1.003 MΩ

5. R_f and R_1 are used for gain, so select R1 and RF = 10KΩ

V. SIMULATION RESULT

After designed the circuit on NI-multisim the suitable results are found on a center frequency of 8 Hz with an amplitude of 5 mV. The frequency response curve of band pass filter are obtained at center frequency (f_C) 2.375 Hz frequency with 6.77 dB. After simulation results, the practical Bandwidth (f_H-f_L) = 2.026 Hz is calculated.

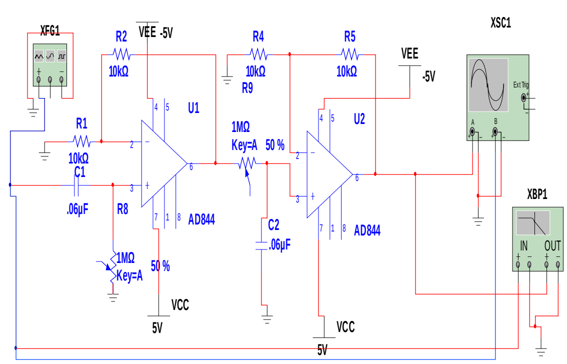

Fig.2: Circuit of band pass filter

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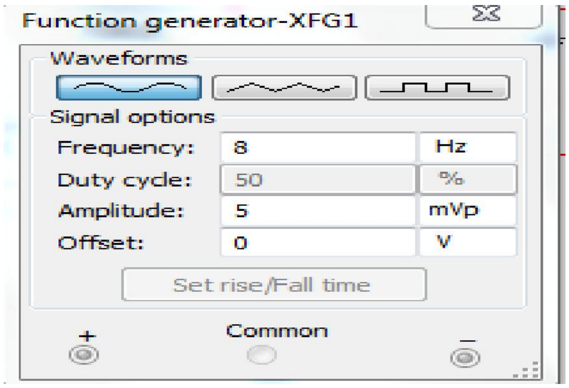

Fig.3: Input from function generator at 8Hz frequency

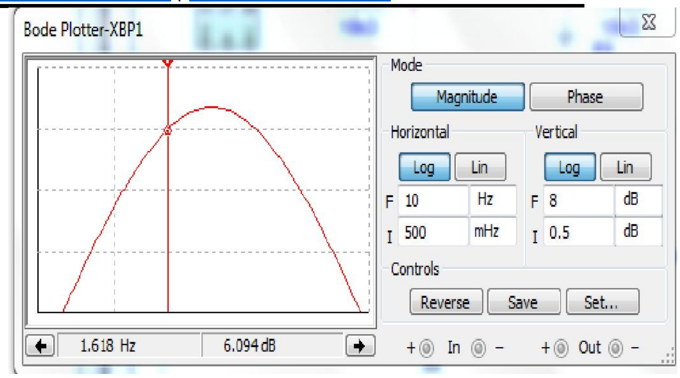

Fig.5 (a): Frequency response curve for band pass filter at low cut off frequency

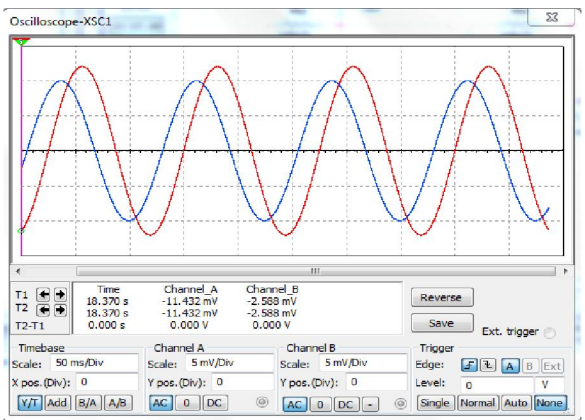

Fig.4: Output waveform of band pass filter

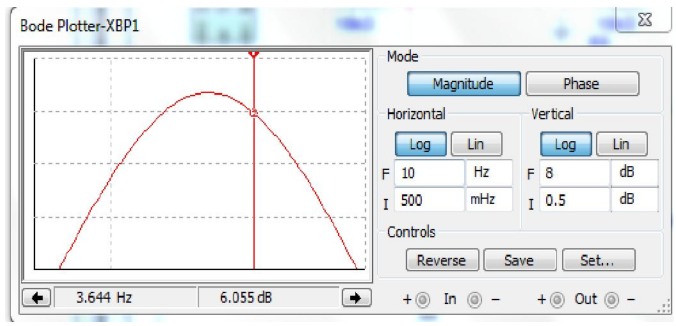

Fig.5 (b): Frequency response curve for band pass filter at high cut off frequency

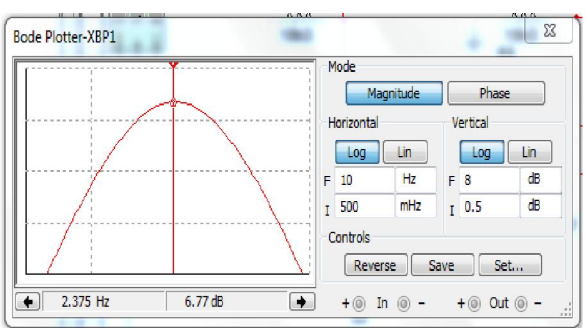

Fig.5: Frequency response curve for band pass filter

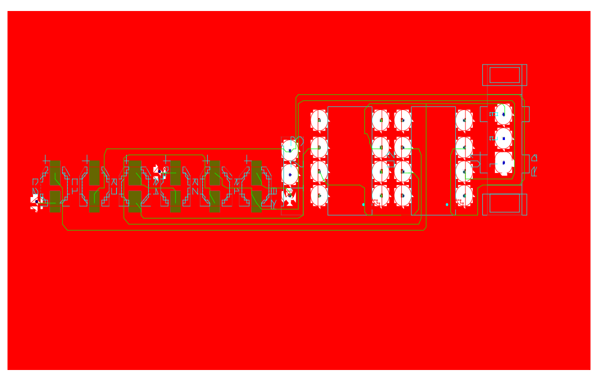

Fig.6: PCB layout using Ultiboard

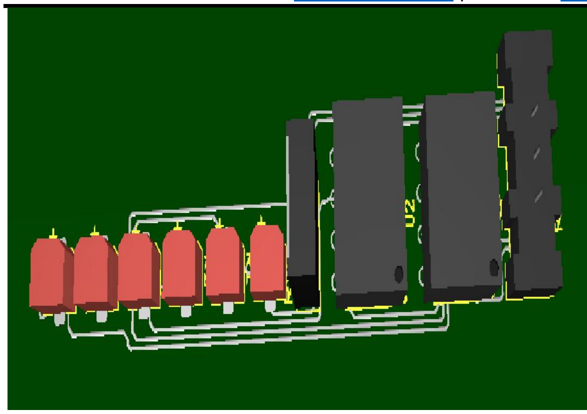

Fig.7: 3D view of PCB

CONCLUSION

In this paper band pass filter has been proposed by cascading a high pass and a low pass filter for ECG signal. Theoretical in this paper the frequencies ranges considered from 0.5-150 Hz with 0.5mV to 5mV amplitude and a center frequency of 8.66 Hz using a very high speed IC AD844. This IC have a high slew rate of 2000 V/µs so , it can be used in place of traditional op-amps due to its much better ac performance, high linearity, and an exceptionally clean pulse response. Because in biomedical signal processing, ECG signal are ranges from 0.5-100 Hz therefore the proposed design provides a satisfactory results at output on a very low frequency from 0.5-150 Hz with an amplitude of 5mV.

In general, 0.67 to 40-Hz bandwidth is for standard ECGs and up to 300 Hz to 1 kHz for pacemaker detection [4]. In this paper, after simulation results, the practical Bandwidth 2.026 Hz is calculated. Which is in the range of 0.67 to 40 Hz bandwidth is for standard ECGs. In this paper the output results are obtained by help of simulation software NI-Multisim.

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