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A High Q Band Pass Filter Using Two Operational Amplifiers

Seema Rana*, Kapil Dev Sharma** and Kirat Pal***

*DAV Centenary Public School, Hardwar – INDIA
**Department of Physics , DAV(PG) College, Dehradun(Uttranchal) - INDIA
***Department of Earthquake Engineering
I. I. T. Roorkee – 247 667,INDIA
E-mail: kirat.pal@gmail.com

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ABSTRACT

A high Q band pass filter using two operational amplifiers is reported. The quality factor Q of the circuit is controllable through a single resistance. The results of experimental and theoretical studies are presented and confirms the theory.

1. Introduction

The application of band pass filter for selecting a band of frequencies is well known in the open literature. In general form the transfer function of a band pass filter is given by

$$T(s) = \frac{a_o s}{a_1 + b_1 s + b_2 s^2} \tag{1}$$

where a_o, a_1, b_1 and b_2 are constants.

The quality factor Q of the band pass filter is governed by the term b_1. It has infinite Q if b_1 approaches zero value but practically it is not possible although some high value up to Q=20 is easily possible.

In the literature number of circuits of band pass filter using operational amplifiers are available [1-5]. Here the new circuit of band-pass filter using only two operational amplifier is presented which has a controllable Q through a single resistance. The experimental results confirm the theory.

2. Circuit Description

Consider the general circuit shown in fig.1.Its voltage transfer function is given by

$$\frac{V_o}{V_i} = \frac{-Z_3/Z_1}{(1 - \frac{Z_3 Z_4}{Z_5 Z_2})} \tag{2}$$

if $Z_2 = Z_1$

$$\frac{V_o}{V_i} = \frac{-Z_3/Z_4}{\left(1 - \frac{Z_3}{Z_1}\frac{Z_4}{Z_5}\right)} \tag{3}$$

put $Z_1 = \frac{1 + sCR}{sC}$ combination of R in parallel with C

$Z_3 = \frac{R}{(1 + sCR)}$ resistance R in series with C

and $Z_4 = R_4$

$Z_5 = R_5$

Equation (3) becomes

$$\frac{V_o}{V_i} = \frac{sCR}{1 + s^2C^2R^2 + sCR(2 - K)} \tag{4}$$

where $K = \frac{R_4}{R_5}$

The actual circuit is shown in fig.2.

The equation (4) represents a high Q band pass transfer function which is controllable through R_4 or R_5.For sinusoidal input s = jω the equation (4) becomes

$$\frac{V_0}{V_i} = -\frac{j\omega CR}{(1 - \omega^2C^2R^2 + j\omega CR(2 - K)} \tag{5}$$

put ωCR = u (normalized from), equation(5) becomes

$$\frac{V_o}{V_i} = -\frac{ju}{(1 - u^2) + ju(2 - K)} \tag{6}$$

Center frequency $u_0 = 1$,and gain $\left|\frac{V_o}{V_i}\right|$ is maximum at this value which is given by

$$\left|\frac{V_o}{V_i}_{\max}\right| = \frac{1}{2 - K} \tag{7}$$

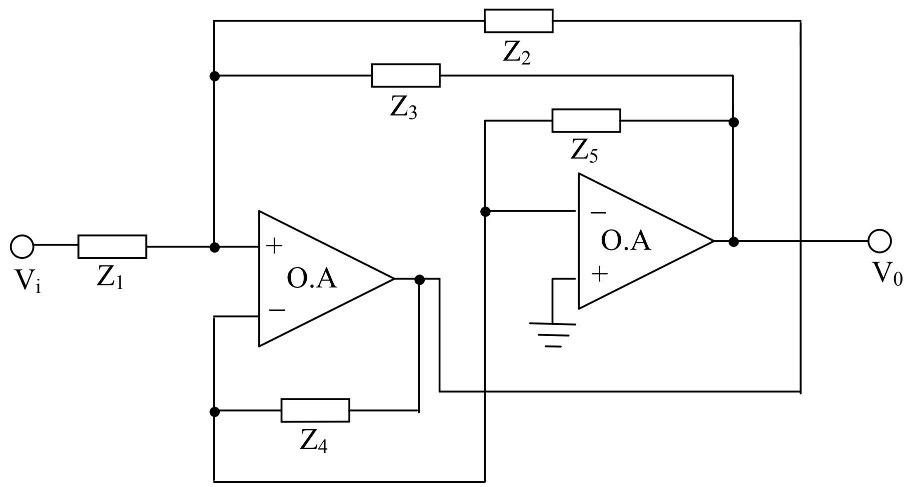

Fig.1. The General Circuit

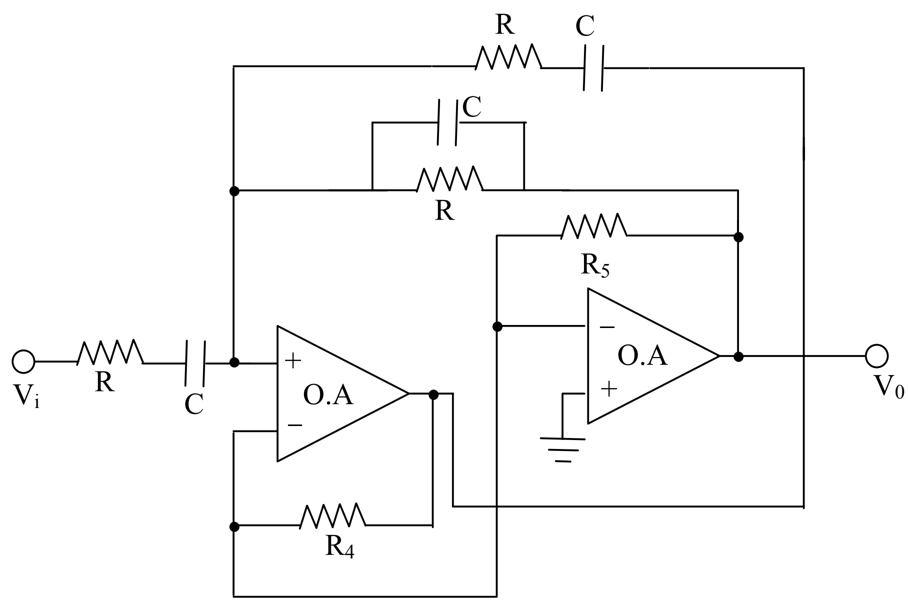

Fig.2. Actual Circuit of High Q Band Pass Filter

The lower and upper cutoff frequency u_l and u_h occurs at $\frac{1}{\sqrt{2}}$ of maximum gain i,e at $\frac{1}{\sqrt{2}} \times \frac{1}{(2-K)}$, and are given as

$$u_l = \frac{-(2-K)+\sqrt{(2-K)^2+4}}{2} \tag{8}$$

$$u_h = \frac{(2-K)+\sqrt{(2-K)^2+4}}{2} \tag{9}$$

The bandwidth of the filter circuit is given by

$$B.W. = u_h - u_l$$

Or $$B.W. = (2-K) \tag{10}$$

The quality factor $Q = \frac{u_o}{u_h - u_l}$

or $$Q = \frac{1}{(2-K)} \tag{11}$$

It is clearly seen from eqn.(11) that Q approaches infinity as K approach the value 2.0.The Q can be controlled by R_4 or R_5.

3. Experimental Results

The circuit was tested for R=10KΩ ,C=0.001µF, R_5=10KΩ and R_4=15KΩ in first experiment and for R=10KΩ ,C=0.001µF R_5=10KΩ and R_4=18KΩ in second experiment. The IC 3140 which is an operational amplifier was used and operated with a ±12V power supply. An input signal of 100mV was given in the frequency range of 1KHz to 100KHz. The results for K= R_4/R_5= 1.5 and K=1.8 are shown in figure -3 and figure-4 respectively.

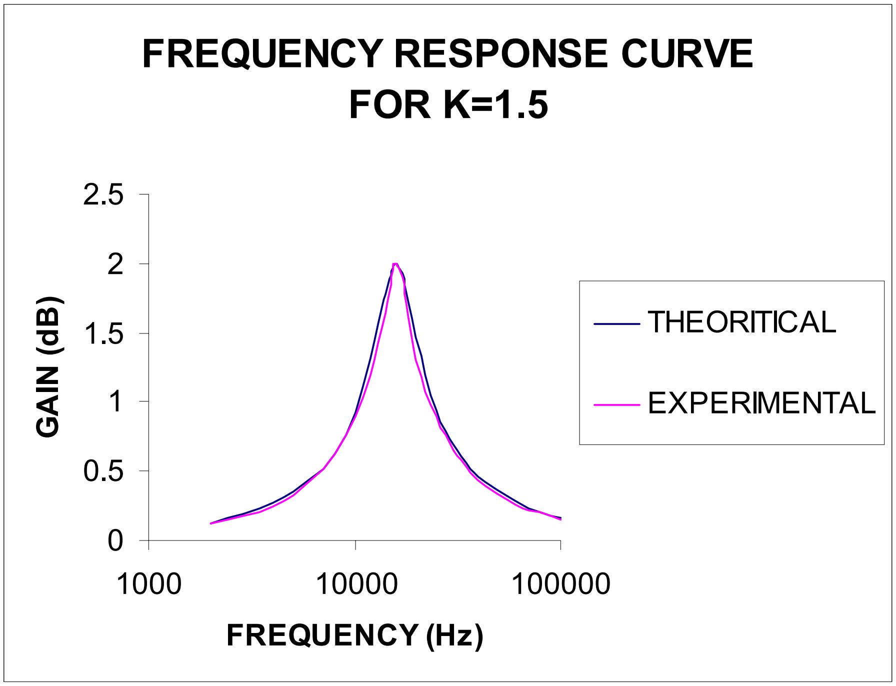

Fig.3. Frequency Response of Band Pass Filter (K=1.5)

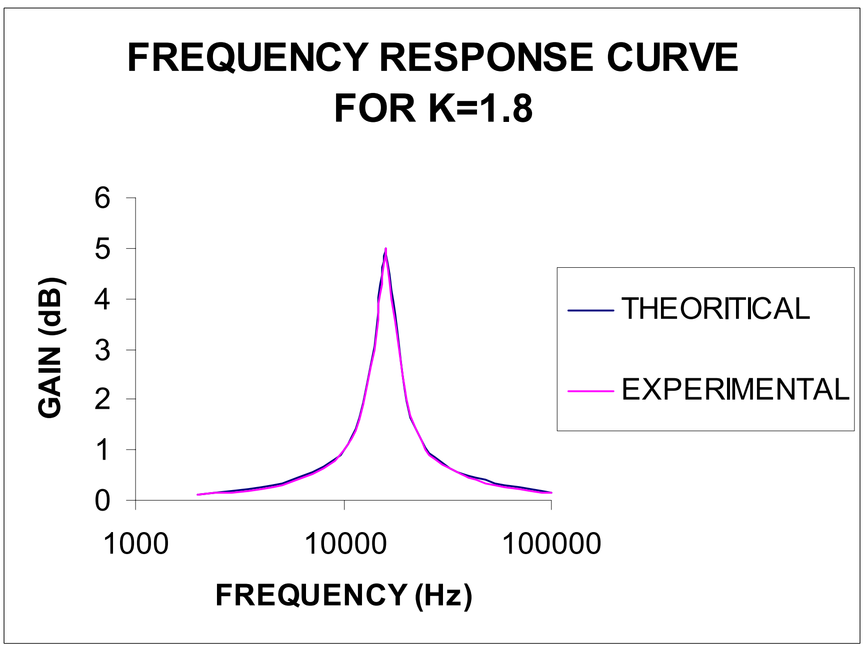

Fig.4. Frequency Response of Band Pass Filter (K=1.8)

4. Conclusions

A new type of band pass filter circuit has been reported. The circuit realises a high Q band pass filter, which is controllable through a single element as a resistance. The results of experimental study confirm the theoretical predictions made.

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