THREE FILTER FUNCTION WITH MULTIPLE FEEDBACK SIGNAL WITH VARIATION IN Q

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Abstract: The proposed circuit is studied by varying circuit merit factor Q (=0.5, 0.9, 1, 3, 5, 7, 9, 10 and 25) with constant center frequency F_0 =100 kHz, R_A=2kΩ and R_B=1kΩ and tapping ratio A=0.9 and B=0.5. The tapping point of A is fixed i.e, A=0.9. This dual tapped third order active-R Filter circuit gives three filter function Low pass response, high pass response and band pass response at different terminals.

***Keywords*- Third order active-R filter, Multiple feedback signal, Cut-off frequency.**

I. Introduction

Active filters can be designed using only resistor and operational amplifiers as the circuit's elements. The reactance for these filters is obtained from the parasitic capacitances associated with the amplifiers [1-10]. The advantage of active-R filter is that it appears at higher frequencies than those realized with op-amp assuming its gain to be infinite. Secondly it gives desire filter characteristics without external capacitors. Here a new dual tap multiple feedback third order active-r filter with variation in circuit merit factor Q realizing a better gain roll-off, minimum center frequency shifting, high Q band pass filter controllable by Q.

II. Circuit Configurations

In the circuit, three op-amps and six resistances are used. The resistances used for different configuration are of 1% tolerance. The most commonly available op-amp. is µA741 were used for designing circuit. The gain bandwidth product value was taken as $5.6x2\pi x10^5$ rad/sec. Three op-amp IC's with almost same value of GB were selected. The proposed filter circuit is designed and studied for dual tap with multiple feedback using operational amplifier and resistor. The filter circuit gives three filter functions: low pass, high pass and band pass at distinct terminals. In the designed circuit three op-amps are used. R_1 is connected in between inverting input of first op-amp and out put of second op-amp which is coupling with second op-amp. of non-inverting input terminal. R_2 is connected in between inverting input terminal of first op-amp and out put of second op-amp which is coupling with third op-amp of non-inverting input terminal. R_3 is connected in between inverting input terminal of first op-amp and output of third op-amp. Negative feedback is incorporated by resistance R_1, R_2 and R_3. Feedback resistance R_1 and R_3 is tapped by positive feedback resistance R_A and R_B respectively.

III. Design equations:-

The transfer function shows op. amp. as an 'integrator' model. It is represented by single pole model and leads to complex gain [1-8].

$$A(S)=\frac{(A_0\omega_0)}{(S+\omega_0)} \quad (1)$$

where,

A_0 = open loop d. c. gain

ω_0 =open loop 3dB bandwidth of the op. amp =2 π_{F0}

GB= $A_0\omega_0$ = gain bandwidth product of the op. amp

For S>> ω_0

$$A(S)=\frac{A_0\omega_0}{S}=\frac{GB}{S} \quad (2)$$

The figure (1) shows the third order active-R filter circuit where the feedback resistance R_3 is tapped at the center and resistance R is connected with multiple feedbacks.

The transfer functions for various outputs are

$$T_{LP}(S) = \frac{-\left(\frac{1}{R_4}\right)(GB_1 GB_2 GB_3)}{S^3 X_1 + S^2 X_2 + S X_3 + X_4} \quad (3)$$

$$T_{BP}(S) = \frac{-\left(\frac{1}{R_4}\right) S\, GB_1 GB_2}{S^3 X_1 + S^2 X_2 + S X_3 + X_4} \quad (4)$$

$$T_{HP}(S) = \frac{\left(\frac{1}{R_4}\right) S^3}{S^3 X_1 + S^2 X_2 + S X_3 + X_4} \quad (5)$$

The circuit has been designed using coefficient-matching technique with general third order filter transfer functions [8]

$$T(S) = \frac{H_3 S^3 + H_2 S^2 + HS + H_0}{S^3 + S^2 \omega_0 \left[\left(\frac{1}{Q}\right) + 1\right] + S\omega_0^2 \left[\left(\frac{1}{Q}\right) + 1\right] + \omega_0^3} \quad (6)$$

Where,

$$X_1 = \left(\frac{1}{AR_1} + \frac{1}{R_2} + \frac{1}{BR_3} + \frac{1}{R_4} - \frac{(1-A)MR_A}{A} - \frac{(1-B)NR_B}{B}\right) \quad (7)$$

$$X_2 = (GB_1 MR_A) \quad (8)$$

$$X_3 = (GB_1 GB_2)\left(\frac{1}{R_2} + (1-B)NR_3\right) \quad (9)$$

$$X_4 = GB_1 GB_2 GB_3 (1-A) MR_1 + NR_B \quad (10)$$

Values of R_1, R_2, R_3 and R_4 can be calculated using these equation for different values Q with F_0 = 100 kHz, R = 470Ω is shown in Table No. 7.1. For practical implementation the value of all resistance must be positive and are impedance scaled up by 100.

IV. Experimental Observations:-

The performance of the circuit is studied for different values of Q. The outputs are taken at three distinct terminals; low pass, high pass and band pass filter responses .The responses plotted for voltage gain with frequency shows excellent performance.

For realization of value of resistances must be positive. Hence there is lower limit of Q of this circuit i.e. Q ≥ 0.2685.

a. **Low pass response:-**

Low pass response of the circuit is shown in figure (7.2). Maximum passband increases as Q increases from Q=0.5 to Q=5. The passband is almost same for Q (= 7, 9, 10 and 25). For Q (=0.5 and 5). -3dB frequency (F_{0L}) remains unchanged i.e, 130 kHz and for Q = 0.9, 1, 3, 7, 9, 10 and 25; F_{0L} remains unchanged i.e, 150 kHz. For Q < 0.9, the observed -3dB cut-off frequency F_{0L} deviates from the designed value and the deviation remains constant as Q increases. Except Q=0.5 and 5. For Q=0.5, the gain roll-off is 15.22 dB per octave for the octave starting at 200 kHz. For Q=0.9, the gain roll-off is 17.50 dB per octave for the octave starting at 200 kHz. For Q=1, the gain roll-off is 16.39 dB per octave for the octave starting at 200 kHz. For Q=3, the gain roll-off is 16.94 dB per octave for the octave starting at 200 kHz. For Q=5, the gain roll-off is 16.61 dB per octave for the octave starting at 200 kHz. For Q=7, the gin roll-off is 14.58 dB per octave for the octave starting at 200 kHz. For Q = 10, the gain roll-off is 14.5 dB per octave for the octave starting at 150 kHz. For Q=25, the gain roll-off is 10 dB per octave for the octave starting at 150

kHz. Overshoot is observed in the passband for Q ≥ 0.5 and increases with Q. The overshoot appears at frequency 110 kHz for
Q (= 0.9, 1, 3, 7, 9, 10 and 25). Peak of the overshoot occurs at a frequency near F_0 except Q=0.5 i.e, at 70 kHz and Q = 5 i.e, at 90 kHz. The graph analysis is shown in table no.7.2.

The circuit works better as low pass filter for 0.5 < Q ≤ 7 with optimum passband gain, minimum center frequency shift, better gain roll-off and maximum overshoot.

b. **High pass response:-**

High pass response of the circuit is shown in figure (7.3). The response shows overshoot for Q ≥ 0.9 and its magnitude increases with increase in Q. The minimum gain roll-off per octave in the stop band increases as Q is increased. The observed -3 dB cut-off frequency F_{0H} shifts from the designed value F_0, except Q = 1. For Q=5 and 25; there is minimum change in F_{OH}. The frequency, at which the gain gets stabilized after overshoot, remains almost constant with changes in Q. The gain roll-off per octave in the stop band increases as Q is increased. The circuit works better as high pass filter for Q=10; with maximum overshoot and little shift in the -3dB cut-off frequency and gain is stabilized at -0.5 dB as compare to other Q. The gain roll - off per octave is 9.85 dB for the octave starting at 50 kHz.

c. **Band pass response:-**

Band pass response of the circuit is shown in figure (7.4). Maximum passband gain increases with increase in Q. The observed center frequency F_{0B} little shift from the designed value Q=10 and 25; for Q (=0.5, 0.9, 1, 5, 7 and 9) the shifting of center frequency is almost same. In leading part and trailing part, the gain roll - off per octave is independent for Q. For instance Q = 10; the gain roll-off per octave is 16.75 dB and 16.15 dB in leading part and trailing part respectively which is starting at 50 kHz and 150 kHz.

The graph analysis is shown in Table No.7.3.

The circuit gives better band pass filter with maximum passband gain, little shift in the center frequency, better gain roll-off per octave in the stop band and optimum bandwidth.

V. Conclusion:-

In low pass response; it gives optimum passband gain, minimum center frequency shift, and better gain roll-off in the stop band with some over shoot. As Q increases the gain roll-off per octave is decreases. In high pass response maximum overshoot is observed. Band pass response provide better passband gain, minimum center frequency shift, maximum gain roll-off per octave in the stop band and better bandwidth with better symmetry of the curve.

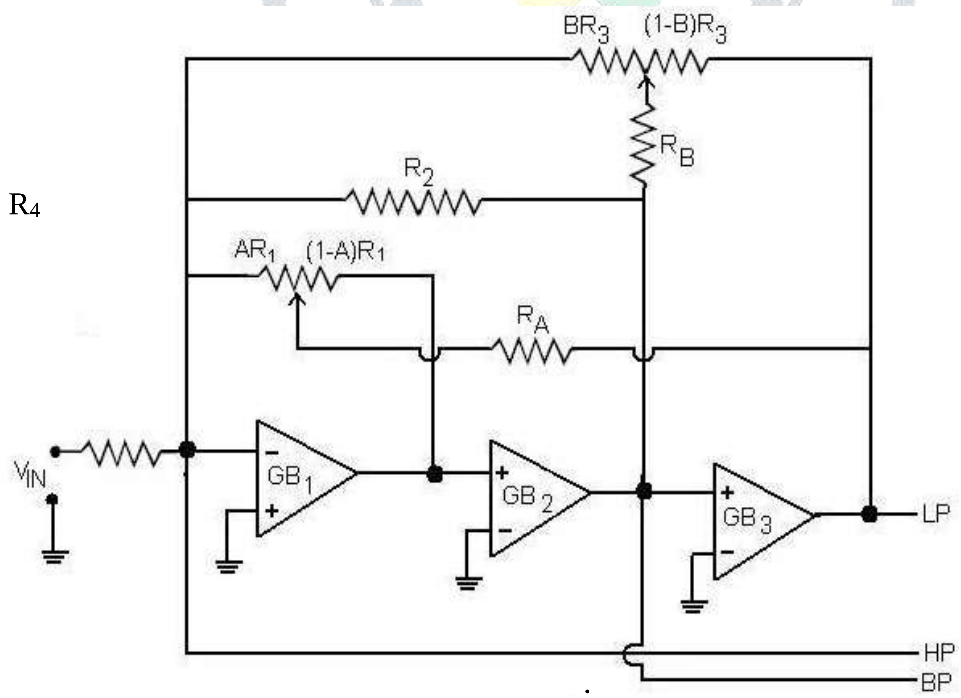

Figure 1. Proposed circuit

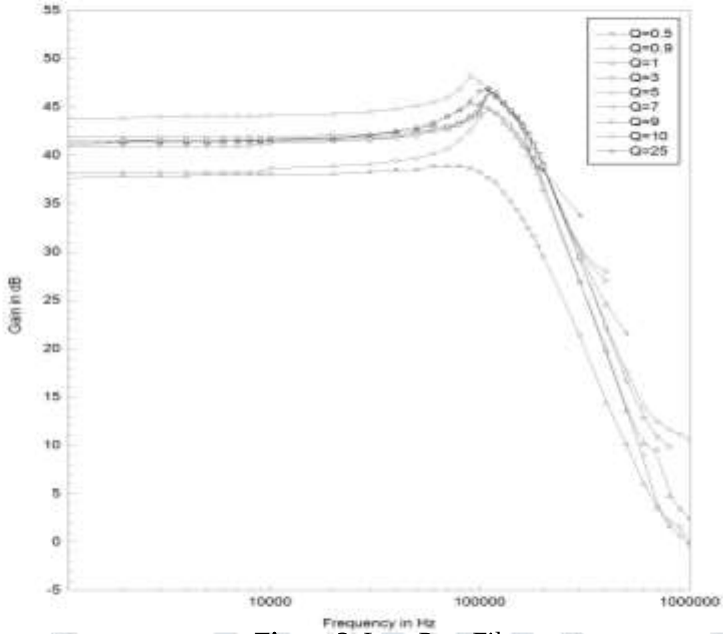

Figure 2. Low Pass Filter

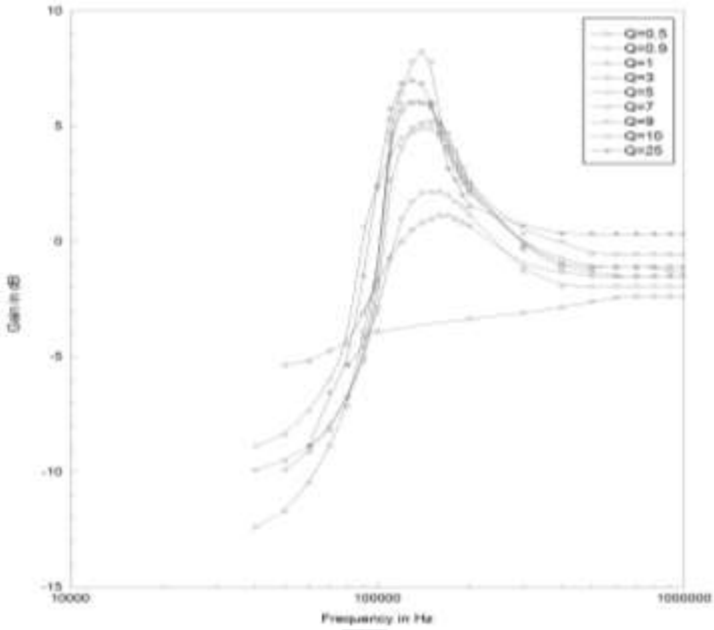

Figure 3. High Pass Filter

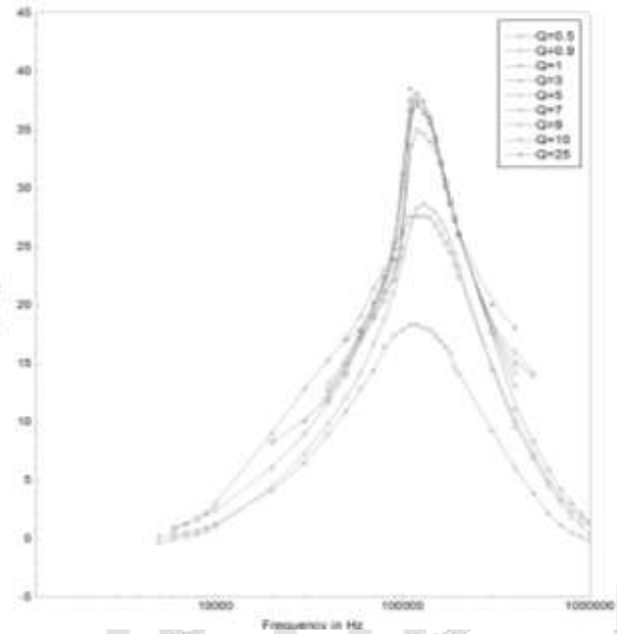

Figure 4. Band Pass Filter

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