International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 4, pp: 694-697 www.ijaem.net ISSN: 2395-5252

Active-R Third Order Band Pass Filter For Fixed Centre Frequency f_0

Dr. D. D. Mulajkar
Department of Physics Satish Pradhan Dnyanasadhana College, Thane, Maharashtra 400604, India

Date of Submission: 02-08-2020 Date of Acceptance: 20-08-2020

ABSTRACT: The circuits using current-mode (CM) building blocks have received considerable attention in many filtering and signal processing applications. Compared to their voltage-mode (VM) counterparts, the current-mode building blocks are attractive because of their wider bandwidth, higher slew rate, and lower power consumptions. In IC technology, it is desirable to operate circuits at low voltages which can be achieved by using CM building blocks. As a large number of op-amp based circuits with elegant realization procedures are already available, it is worthwhile to convert them into the circuits based on current-mode building blocks. In this paper, a realization of a current mode third order band pass filter is described. The proposed circuit employs an operational amplifier as the basic building unit. The filter circuit realizes quadratic work function. It provides electronically tuning capability of the filter characteristics. The proposed circuit works ideal for Center frequency fo = 10 k and Circuit merit factor Q > 1. The gain roll-off in this configuration is 18dB/octave. The circuit is suitable for monolithic integration and high frequency operation. The filters developed were successful in obtaining passive sensitivities less than unity in magnitude and active sensitivities are one third in magnitude, which is a noteworthy achievement.

Key Words: Current mode filter, third order, band pass, circuit merit factor, center frequency.

I. INTRODUCTION:

At present, there is a growing interest in designing capacitor-less, resistor-less current mode active only filters using only active elements such as Operational amplifier [OA], Operational transconductance amplifiers [OTAs]. Current mode filters have many advantages compared with their voltage mode counterparts. Current mode filters have large dynamic range, higher bandwidth, greater linearity, simple circuitry, low power consumption etc. Many circuits for realizing voltage mode filters have been proposed by researchers. The realization of current mode transfer function is a topic of considerable interest for researchers. MisamiHigashimura proposed a synthesis of current mode high pass transfer function using op-amp pole [Higashimura, 1993]. Extensive work has been done employing active devices such as OAs and OTAs [2, 3]. Due to their many advantages there is growing interest in designing and implementing current mode active filters using second generation current conveyors [CCIIs]. Several implementations of current mode CCII-based filters are available in literature. Current mode active filters are also designed with second generation dual output current conveyors [DO-CCII] [10].

This paper focuses on a third order current mode active-R filter with quadratic transfer function. The proposed circuit is solely designed with op-amps and resistors and hence suitable for high frequency operation. The filter has low passive sensitivities. The gain roll-off is 40 dB/decade.

1. Circuit configuration and analytical treatment:

The open loop gain of an OA is represented by the well-known first order pole model as

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

Where, A_0 : Open loop D.C.gain of op-amp.

ω_0 : Open loop – 3dB bandwidth of the op-amp = $2\pi f_0$

$A_0\ \omega_0 : \beta_i$ = gain-bandwidth product of op-amp.

For $S >> \omega_0$

$$A(S) = \frac{A_0 \omega_0}{S} = \frac{\beta_i}{S}$$

This model of OA is valid from a few kHz to few hundred kHz.

The derived transfer function of the circuit for band pass function is given by following equation (1)

$$T_{BP} = \frac{g_2 \beta_1 \beta_2 k_1 k_2 S}{(g_0 + g_1 + g_2 + g_3 + g_{1b} k_1) S^3 + g_1 \beta_1 k_1 S^2 + g_2 \beta_1 \beta_2 k_1 k_2 S + g_3 \beta_1 \beta_2 \beta_3 k_1 k_2 k_3}$$

Where,

$$k_1 = \frac{g_{1a}}{g_{1a} + g_{1b}}$$

$$k_2 = \frac{g_{2a}}{g_{2a} + g_{2b}}$$

The circuit was designed using coefficient matching technique i.e. by comparing these transfer functions with general second order transfer functions is given by following equation (2)

$$T_S = \frac{\alpha_3 S^3 + \alpha_2 S^2 + \alpha_1 S + \alpha_0}{S^3 + \omega_0\left(1+\frac{1}{Q}\right)S^2 + \omega_0^2\left(1+\frac{1}{Q}\right)S + \omega_0^3}.$$

Comparing equations (1) and (2), we get,

$$\omega_0^3 = g_3\beta_1\beta_2\beta_3 k_1 k_2 k_3$$

$$\omega_0^2\left(1+\frac{1}{Q}\right) = g_2\beta_1\beta_2 k_1 k_2$$

$$\omega_0\left(1+\frac{1}{Q}\right) = (g_1\beta_1 + g_3\beta_3)k_1$$

$$g_0 + g_1 + g_2 + g_3 + g_{1b}k_1 = 1$$

$$k_1 = \frac{g_{1a}}{g_{1a} + g_{1b}}$$

$$k_2 = \frac{g_{2a}}{g_{2a} + g_{2b}}$$

But,

$$g_{1b}k_1 \ll 1$$

Therefore,

$$g_0 + g_1 + g_2 + g_3 = 1$$

Using these equations, the values of g_1, g_2 and g_3 are calculated for different values of merit factor Q and frequency f_0.

2. Proposed Circuit Diagram:

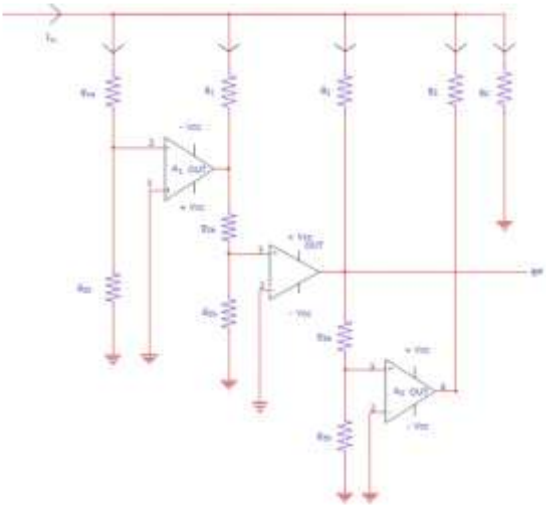

Fig (1) Circuit diagram of third order electronically tunable CM filter

3. Band-pass response

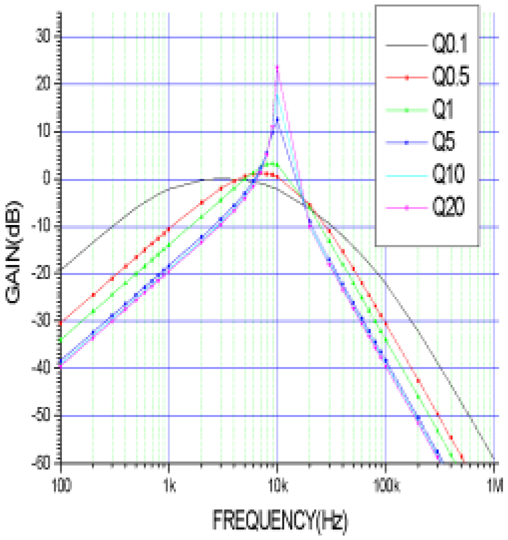

Fig (2) Band-pass response for Central frequency f_0 = 10 kHz

Band-pass response for f_0 = 10 kHz								
Q	Max. Pass Band Gain (dB)	f_1 (kHz)	f_2 (kHz)	Band-width (kHz)	Gain Roll-off in stop band			
					Leading Part		Trailing Part	
					dB/Octave	Octave Starting at (kHz)	dB/Octave	Octave Starting at (kHz)

0.1	0	0.85	11.43	10.6	5.1	0.6	4.1	10
0.5	1.25	2.6	15.2	12.6	6.1	0.4	10.0	20
					6.5	2.0		
1.0	3.4	3.5	15.2	11.7	6.2	0.8	12.0	30
					6.0	2.0		
5.0	12.5	5.0	16.4	11.4	6.2	2.0	11.2	20
					7.2	5.0		
10	17.6	5.2	17.0	11.8	6.0	1.0	13.3	20
					8.1	6.0		
20	23.4	5.4	17.3	11.9	5.4	1.0	13.2	20
					8.1	6.0		

Table 1: Analysis of Band pass response

5. Sensitivity:

Equations of the ω_0 and Q Sensitivities of the transfer function with respect to the parameters k_1, k_2, k_3, β_1, β_2, β_3, g_0, g_1, g_2 and g_3 are as follows. It is found that the proposed circuit has very low sensitivity

ω_0 Sensitivities:

$$S_{g_0}^{\omega_0} = -\frac{1}{3}\left[\frac{g_0}{g_0 + g_1 + g_2 + g_3}\right]$$

$$S_{g_1}^{\omega_0} = -\frac{1}{3}\left[\frac{g_1}{g_0 + g_1 + g_2 + g_3}\right]$$

$$S_{g_2}^{\omega_0} = \frac{1}{3}\left[\frac{g_2}{g_0 + g_1 + g_2 + g_3}\right]$$

$$S_{g_3}^{\omega_0} = \left(\frac{1 - g_3}{3}\right)$$

$$S_{k_1}^{\omega_0} = S_{k_2}^{\omega_0} = S_{k_3}^{\omega_0} = \frac{1}{3}$$

Q Sensitivities

$$S_{K_1}^{Q} = -\left[\frac{1+Q}{3}\right]$$

$$S_{K_2}^{Q} = -\left[\frac{1+Q}{3}\right]$$

$$S_{K_3}^{Q} = \left[\frac{2(1+Q)}{3}\right]$$

$$S_{g_0}^{Q} = -\left[\frac{2g_0(1+Q)}{3}\right]$$

$$S_{g_1}^{Q} = -\frac{g_1(1+Q)}{(g_1+g_3)}$$

$$S_{g_2}^{Q} = -(1+Q)(1+g_2)$$

$$S_{g_3}^{Q} = -\frac{g_1(1+Q)}{(g_1+g_3)}$$

β Sensitivities:

$$S_{\beta_1}^{Q} = -\left[\frac{1+Q}{3}\right]$$

$$S_{\beta_2}^{Q} = -\left[\frac{1+Q}{3}\right]$$

$$S_{\beta_3}^{Q} = \left[\frac{2(1+Q)}{3}\right]$$

$$S_{\beta_1}^{\omega_0} = S_{\beta_2}^{\omega_0} = S_{\beta_3}^{\omega_0} = \frac{1}{3}$$

II. RESULT AND DISCUSSION

The circuit performance is studied for different values of Merit factors with circuit Central frequency of 10 kHz. The general operating range of this filter is 10 Hz to 1MHz.The value of β_1, β_2 and β_3 is 6.392×10^6 for LF 356 N.

Q	$R_0(\Omega)$	$R_1(\Omega)$	$R_2(\Omega)$	$R_3(\Omega)$
0.1	1.3	5	235	131K
0.2	1	8.5	431	131K
0.5	1.2	17	862	131K
1.0	1	25	1293	131K
5.0	1	42	2155	131K
10	1	46	2351	131K

Table (2): Resistor values for f_0 =10 kHz

Maximum pass band gain for Q= 0.1 is 0 dB and for Q=20, it is 23.4 dB. The value of maximum pass band gain increases with increase in Q. It is also seen that the curves become sharper with increase in value of Q. The curves are more symmetric for higher values of Q compared to lower values. Gain roll-off per octave near pass band remain almost the same (about6.1 dB) in the leading part for 0.5 $\leq Q \leq 10$ Gain roll-off per octave in the trailing part increases with increase in Q. It has value 4.1 dB/ octave for Q=0.1 for octave starting at 10 kHz and 13.2 dB/ octave for Q=20 for octave starting at 20 kHz.

-3 dB bandwidth has value of 11.4 kHz for Q=0.1. It increases to 12.6 kHz for Q=0.5 then remain almost same (11.8 kHz) for $Q \geq 1$

III. CONCLUSION:

In this paper, a realization of a current mode third order high pass and low pass filter is described. The proposed circuit employs operational amplifier as the basic building unit. The filter circuit can realize transfer functions and circuit characteristics can be electronically tuned. The bandwidth of the filter circuit increases with increase in center frequency. The value of the bandwidth is nearly equal to the center frequency. For higher values of f_0, filter can be used for wide bandwidth and for lower values of f_0, it can be used for narrow bandwidth. The circuit has passive sensitivities no more than unity. The circuit is suitable for high frequency operation and monolithic integration.

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