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Active-R second order feed forward electronically tunable CM low pass filter for different central frequencies f_0.

Dr.Proddutury Indira
Associate Professor - Physics
Bhavan's New Science College, Narayanguda, Hyderabad

Abstract

In this paper a new electronically tunable feed forward current-mode second order low pass filter is proposed. The proposed circuit employs OP-AMP as an active building block. With current input the filter can realize low pass responses in current mode. The filter circuit realizes calculated transfer function. The proposed circuit provides the following important and desirable features 1) minimum active and passive elements are employed 2) Responses are electronically tunable 3) Sensitivities are low 4) Suitable for high frequency operation and monolithic implementation.

Keywords: Current-mode, filter circuit , passive elements, tunable , high frequency.

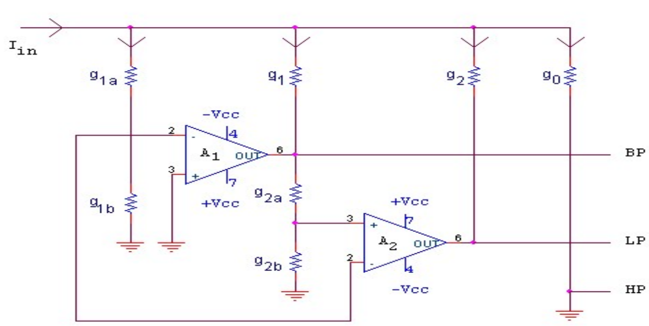
1. Introduction

Current-mode active filters have received significant attention [1-8].They are becoming popular because of many advantages over voltage-mode filters. As compared to voltage-mode circuits, current-mode circuits can generally operate with low voltages and have higher bandwidth and slew rate [4,5].In current-mode circuits, output is controlled by input current.

The second order feed forward active-R filter is designed and realized using Operational Amplifiers. It is an internally compensated op-amp. An internally compensated Operational Amplifier is represented integrator model [6-8].The gain of such amplifier changes at the rate of 6 dB/octave (i.e.20 dB/decade). Active-R circuit contain only op-amps and resistors which makes them suitable for high frequency operation and integration with the bipolar monolithic technology [9-16]

2. Proposed Circuit configuration

In this circuit sinusoidal low current signal is applied at inverting terminal of first op-amp through first voltage divider arrangement (formed by g_{1a} and g_{1b}). Non-inverting terminal of first op-amp is grounded. The op-amps are coupled such that output of first op-amp is connected to non-inverting input of second op-amp through second voltage divider arrangement (formed by $g_{2a}$and g_{2b}).The feed forward is provided by connecting the input signal to the inverting terminal of second OA. The negative feedback is incorporated by resistors g_1 and g_2 .Output of second op-amp through resistor g_2 gives low pass function.



Circuit diagram of Universal Second order current-mode filter

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3. Circuit analysis and design equations:

Transfer function of the circuit for low-pass T_{LP} is

$$T_{LP}=\frac{g_2\beta_2}{(g_0+g_1+g_2+g_{1b}k_1)S^2+(g_1\beta_1+g_2\beta_2)k_1S+g_2\beta_1\beta_2k_1k_2}$$

1

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 we get,

$$\frac{\omega_0}{Q}=(g_1\beta_1+g_2\beta_2)k_1$$

$$\omega_0^2=g_2\beta_1\beta_2k_1k_2$$

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

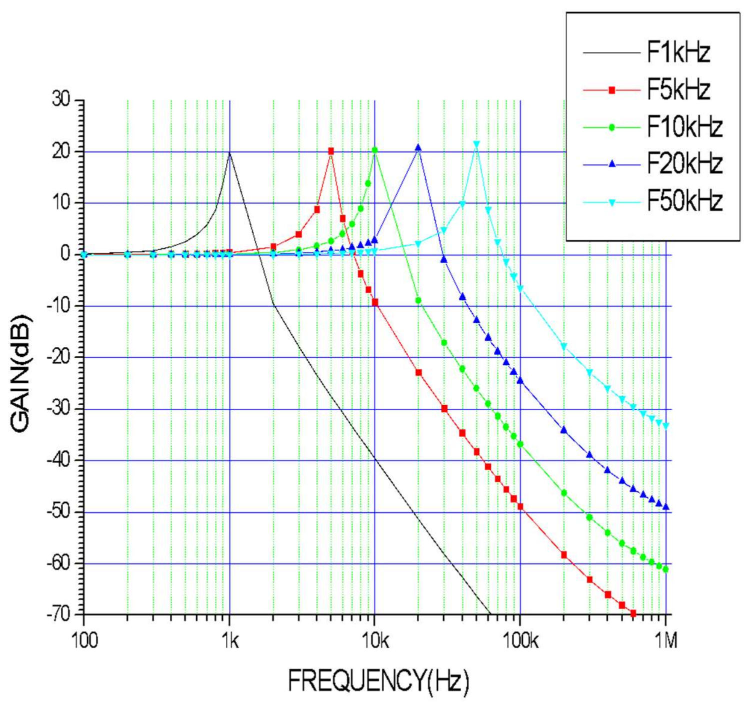
But,

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

Therefore $g_0+g_1+g_2=1$

Using these equations, the values of g_0, g_1 and g_2 are calculated for different values of merit factor Q and frequency f_0.

A. Low-pass response:



Low-pass response for Q =10

Graph Analysis Low-pass response for Q = 10							
f_0 (kHz)	Max. Pass Band Gain dB	F_{OL} (kHz)	$f_0 \sim F_{OL}$ (kHz)	% Change in F_{OL}	Overshoot in pass band dB	Gain Roll-off in stop band	
						dB/Octave	Octave Starting at (kHz)
1	5.93	1.71	0.71	42	20	12.8	3
						11.3	20
5	4.12	7.83	2.83	36	20	14.0	10
						10.5	50
10	2.74	17.33	7.33	42	20.2	12.1	30
						9.5	100
20	2.85	32.5	12.5	38	20.6	11.7	50
						6.6	300
50	4.89	86	36	42	20.5	12.9	80
						5.9	400
F_{OL} : - 3dBfrequency					f_0: Center frequency		

5. RESULTS AND DISCUSSION

The circuit performance is studied for different values of Central frequencies with circuit merit factor Q = 10. The general operating range of this filter is 10 Hz to 1MHz. The value of $\beta_1 = \beta_2 = 2\pi\ (6.392)\ X\ 10^6$ [rad/sec] for LF 356 N. The filter response is studied for Central frequencies f_0 = 1 kHz, 5 kHz, 10 kHz,20 kHz and 50 kHz. The values of resistors calculated for Q =10 are tabulated.

f_0(kHz)	$R_0(\Omega)$	$R_1(\Omega)$	$R_2(\Omega)$
1	1	5.2k	260k
5	1	1.3k	10.4k
10	1	633	2586
20	1	420	647
50	1	6020	103

Table 2: Resistor values for Q=10

It is found that - 3 dB frequency i.e. cutoff frequency F_{OL} for f_0 = 1 kHz is 1.71 and for f_0 = 10 kHz, it is 17.33 kHz. It further increases to 86 kHz for f_0 = 50 kHz. This shows that - 3 dB frequency i.e. cutoff frequency F_{OL} increases with increase in central frequency f_0.

Observed - 3 dB frequency F_{OL} shifts from the designed value f_0.Percentage shift in F_{OL} with respect to f_0 shows no trend as such. For instance, for f_0 = 1 kHz, 10 kHz and 50 kHz, the percentage shift is 42 % whereas for f_0 = 5 kHz, percentage shift is 36 % and 38 % for f_0 = 20 kHz.

Overshoot of about 20 dB is observed for f_0 = 1, 5 and 10 kHz whereas curves for f_0 = 20 and 50 kHz peaks at 20.6 dB and 20.5 dB respectively. Overshoot occurs at the designed value f_0.No shift in center frequency is observed.

Gain roll-off per octave in stop band near the cutoff frequency is higher as compared to its value away from the cutoff frequency. In other words, gain roll-off decreases with increase in input signal frequency. The gain roll-off is almost double near pass band that of away for responses of 20 and 50 kHz.

The maximum pass band gain is 5.93 dB for central frequency of 1 kHz and decreases with increase in central frequency.

Thus the filer circuit exhibits excellent low-pass characteristics such as better gain roll-off per octave near pass band, no center frequency shift, and low pass band gain [18].

Sensitivities:

Equations of the ω_0 and Q Sensitivities of the transfer function with respect to the parameters k_1, k_2, β_1, β_2, g_0, g_1 and g_2 are as follows.

ω_0 Sensitivities:

$$S_{K_1}^{\omega_0} = S_{K_2}^{\omega_0} = \frac{1}{2}$$

$$S_{g_0}^{\omega_0} = -\frac{1}{2}\left(\frac{g_0}{g_0+g_1+g_2}\right) \quad S_{g_1}^{\omega_0} = -\frac{1}{2}\left(\frac{g_1}{g_0+g_1+g_2}\right) \quad S_{g_2}^{\omega_0} = \frac{1}{2}\left(\frac{g_0+g_1}{g_0+g_1+g_2}\right)$$

Q Sensitivities

$$S_{K_1}^{Q} = -\frac{1}{2}\ ,\ S_{K_2}^{Q} = \frac{1}{2}$$

$$S_{g_0}^{Q} = -\frac{1}{2}\left(\frac{g_0}{g_0+g_1+g_2}\right)$$

$$S_{g_1}^{Q} = -\frac{1}{2}\left(\frac{g_0 g_1}{g_1+g_2}\right)$$

$$S_{g_2}^{Q} = \frac{(g_1+g_2)-g_0 g_2}{2(g_1+g_2)}$$

β Sensitivities:

$$S_{\beta_1}^{\omega_0} = S_{\beta_2}^{\omega_0} = \frac{1}{2}$$

$$S_{\beta_1}^{Q} = -\frac{1}{2}$$

$$S_{\beta_2}^{Q} = \frac{1}{2}$$

CONCLUSION

In this paper a realization of an electronically tunable feed forward current-mode second order low pass filter is described. The proposed circuit employs OP-AMP as an active building block. With current input the filter can realize low pass responses in current mode. The filter circuit realizes calculated transfer function. The proposed circuit has minimum active and passive elements, low active and passive sensitivities, suitable for high frequency operation and monolithic implementation. The circuit shows excellent performance except low values of gain roll-off per octave.

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References:

1. S.K.Mitra, Analysis and Synthesis of Linear Active Networks. New York: Wiley, 1969.
2. G.Daryani, Principles of Active Network Synthesis and Design. New York: Wiley, 1976.
3. R.Schaumann and M.E.Valkkenburg, Design of Analog Filters. New York: Oxford Univ.Press, 2004.
4. J.Ramirez-Angulo and E.Sanchez-Sinencio,"High frequency compensated CM ladder filters using multiple output OTAs" IEEE Trans.Circuits Syst.,Analog,Digital signal Process,vol.41,no.9,pp 581-586, Sept.1994.
5. National Semiconductor Application Note OA-30,"Current vs. voltage feedback amplifiers," 1998.
6. Michel A. Soderstrand,"Design of active-R filters with only resistors and operational amplifiers,"Int.J.Electronics, vol.40 (No.5), pp.417-432,1976.
7. S.Srinivasan,"Synthesis of transfer functions using operational amplifier pole", Int.J.Electronics vol.40 (1), pp.5 -13, 1976.
8. G.N.Shinde, P.D.Achole and P.R.Mirkute,"Second order active-R filter with multiple feed Back for different Q", Indian Journal of Physics, vol.77B (2), pp.237-239, 2003.
9. Masami Higashimura,"Active-R realization of current mode high-pass filter", Int.J.Electronics. Vol.73, No.6, 1279-1283, 1992.
10. "Active and Passive Filter Design", Lawrence P. Huelsman, McGraw-Hill International Editions, New York, 1993.
11. "Passive and Active filters: Theory and Implementation", Wai-Kai-Chen, John Wiley & Sons, New York, 1986.
12. "Network Theory and Filter Design", Vasudev K. Aatre, Wiley eastern Limited, New Delhi, 2/e, 1986.
13. "Op-amps and Linear Integrated circuits", Ramakant A.Gayakwad, Prentice Hall of India Private Limited, New Delhi, 1998.
14. "Operational Amplifiers", Clayton G.B., ELBS Publication London , II Edition ,1986.
15. "PhD thesis submitted to Dr.B.A. Marathwada University, Aurangabad", Dr. G. N. Shinde , 1998.
16. "M. Phil. Dissertation Submitted to Shivaji University, Kolhapur", Dr. G. N. Shinde 1994.
17. "Linear Circuits", M. E. Van Valkenburg and B.K. Kinariwala, Prentice Hall of India.