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FREQUENCY RESPONSE OF ELECTRONICALLY TUNABLE SECOND ORDER CURRENT-MODE HIGH PASS FILTER FOR FIXED CIRCUIT MERIT FACTOR

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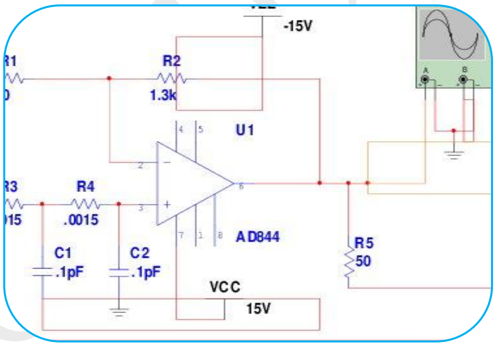
ABSTRACT

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.



A novel single-input current-mode active-R filter using two operational amplifiers (OAs) and resistors is presented. The circuit is fully programmable and implements high pass (HP) functions. The availability of currents at high impedances facilitates cascadibility feature. The filter performance factors center frequency (ω_0), bandwidth (ω_0/Q), quality factor (Q) and gain (G) are electronically tunable. This circuit can realize quadratic transfer function.

Paper includes theoretical frequency response of second order high pass filter for variable cut off frequency with fixed Q. The circuit is suitable for high frequency operation and monolithic integration. The proposed second order high pass filter works ideal for Q = 10 and central frequency from 1 kHz to 50 kHz. The gain roll-off is 40 dB/decade. The designed filter has passive sensitivities less than unity magnitude and active sensitivities half in magnitude.

KEYWORDS: *Current mode filter, second order, high pass, center frequency, circuit merit factor.*

1.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 topic of considerable interest for researchers. Misami Higashimura 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 duel output current conveyors [DO-CCII] [10].

This paper focuses on second 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.

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 by resistors g_1 and g_2 .Output of first op-amp gives high pass function.

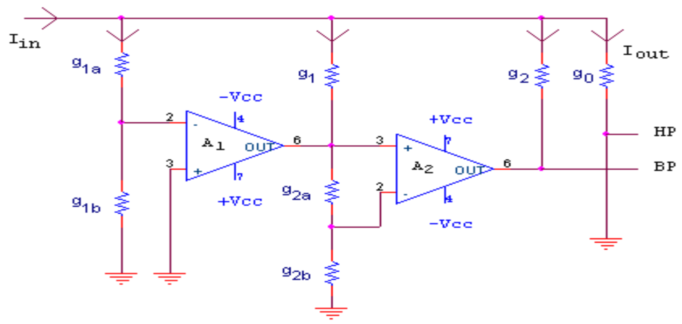


Fig 1: Circuit diagram of Second order current-mode filter

3. CIRCUIT ANALYSIS AND DESIGN EQUATIONS:

Transfer function of the circuit for high pass T_{HP} is calculated as,

$$T_{HP} = \frac{g_0 S^2}{(g_0+g_1+g_2+g_{1b}k_1)S^2+(g_1\beta_1)k_1 S+g_2\beta_1\beta_2(1-k_1)k_2} \qquad (1)$$

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 is given by,

$$T(S) = \frac{\alpha_2 S^2+\alpha_1 S+\alpha_0}{S^2+\frac{\omega_0}{Q}S+\omega_0^2} \qquad (2)$$

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

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

$\omega_0^2 = g_2\beta_1\beta_2(1-k_1)k_2$

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

But,

$g_{1b}k_1 << 1$

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.

4. HIGH PASS RESPONSE FOR CIRCUIT MERIT FACTOR Q = 10

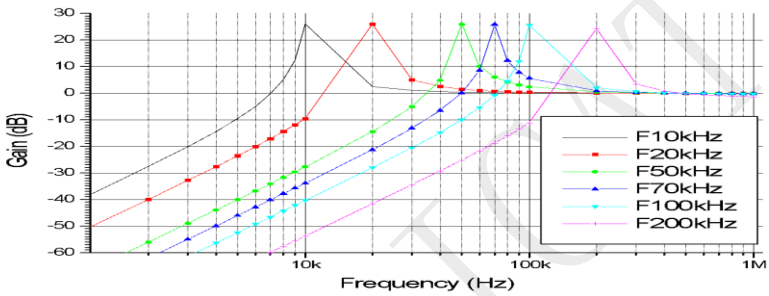


Fig 2: High-pass response for Q =10

High-pass response for Q = 10								
Sr. No.	F_0 (KHz)	F_{0H} (KHz)	F_0 - F_{0H} (KHz)	% Change in F_{0H}	Gain Roll-off /Octave in the stop band		Overshoot in the pass band	
					dB /Octave	Octave start at (KHz)	dB (KHz)	F_S (KHz)
1	10	6.46	3.64	56	14.8	6	25.88	66.71
2	20	11.45	8.55	75	15	30	26	99.36
					12	6		
3	50	31.82	18.28	57	14.8	40	26	247.8
					12.1	7		
4	70	45.58	24.42	53	14.8	60	26	287
					12.1	10		
5	100	65.22	34.78	53	15.1	90	26	352
					12.1	20		
6	200	117.55	82.45	70	13.9	100	26	601
					12.1	20		
F_{0H} : - 3dBfrequency					F_0:Center frequency			

5. RESULT 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 , 50 kHz and 70 kHz.

The - 3 dB frequency i.e. cutoff frequency F_{OH} for f_0 = 10 kHz is 6.46 and for f_0 = 20 kHz, it is 117.55 kHz. Increase in centre frequency causes increase in cutoff frequency. Percentage shift in observed - 3 dB frequency with respect to center frequency has minimum value of 53 for f_0 = 70 kHz and 100 kHz. It has maximum value of 75 for f_0 = 20 kHz.

The gain roll-off per octave in stop band remain constant at 14.8 dB near pass band for 10 kHz $\le \le f_0 \le \le$ 70 kHz. For f_0 = 100 kHz, gain roll-off per octave in stop band has value 15.1 dB for octave 90 kHz to 180 kHz and for f_0 = 200 kHz , it is 13.9 dB for octave 100 kHz to 200 kHz. It is found that in the far end region of stop band; all responses have almost constant value of 12.1 dB/octave. This is close to standard value for second order filter.

Overshoot is seen in the response for every centre frequency f_0.The magnitude of peak gain for all responses remain constant to 26 dB. Overshoot occurs at f_0 i.e. there is no shift in center frequency. Gain gets stabilized at 0 dB for 10 kHz $\le \le f_0 \le \le$ 100 kHz. No stabilization of gain is seen in the response for f_0 = 20 kHz.

Thus the filter circuit shows better high-pass characteristics such as zero center frequency shift, ideal gain roll-off per octave and stability of gain.

6. SENSITIVITIES:

Equations of the ω_0 and Q Sensitivitiesof 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:

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

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

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

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

Q Sensitivities

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

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

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

β Sensitivities:

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

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

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

7. CONCLUDING REMARKS:

A realization of current-mode second order feed forward filter has been proposed. The Filter is built with two internally compensated op-amps. Low sinusoidal current is applied at the inverting terminal of first op-amp through voltage divider. The input signal is fed forward to the inverting terminal of second op-amp. The filter designed has low active and passive sensitivitiesless than unity.The filter circuit shows better high-pass characteristics such as zero center frequency shift, ideal gain roll-off per octave and stability of gain.

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