International Journal of Electronic Networks, Devices and Fields.
ISSN 0974-2182 Volume 6, Number 1 (2014), pp. 1-10

http://www.irphouse.com

Third-Order Switched-Capacitor Tunable Bandwidth Filter with Multifunction Signal for Different Center Frequency (f_0)

[1]Adnan Abdullah Qasem* and [2]G. N. Shinde

[1]School of Physics, SRTM University, Nanded, Maharashtra, India
Email: almogammer80@gmail. com
[2]Principal, Indira Gandhi (SR) College, CIDCO, Nanded, Maharashtra, India
Email: shindegn@yahoo. co. in
**Address for correspondence*

ABSTRACT:

The study proposes Third-Order Switched-Capacitor Tunable Bandwidth Filter with Multifunction Signal for different Center Frequencies (f_0) Configuration. This circuit is designed for a circuit merit factor Q= 1. This paper discusses a new configuration to realize the third-order low pass, band pass, and high pass. The proposed circuit implements three filter functions low pass, band pass, and high pass simultaneously in single circuit. The circuit uses an OP-AMP and MOSFET with Capacitor as Switched-Capacitor. The filter circuit can be used for both narrow as well as wide bandwidth. Also, this circuit works for the tunable bandwidth. For various values of cut-off frequencies the behavior of circuit is studied. The circuit works properly only for higher center frequencies when f_0 >20 KHz. The circuit shows a better response for f_0 >20 KHz. Also, the Stabilization of gain for High pass function can be achieved at 0dB for f_0<60KHz. The Low pass filter function works practically only for higher center frequencies. The advantages of this circuit are the reduction in size and weight, the increase of circuit reliability, and it is more economical and easier for manufacturing.

KEYWORDS: Third-order filter, multifunction signal, passband, Tunable Bandwidth, cut-off frequency.

1. INTRODUCTION:

Conventional analog circuits use the ratio of resistance to set the transfer function of the filter circuits. The values of RC product determine the frequency responses of these circuits [1-2]. A switched-capacitor can replace a resistor [2]. MOSFET technology can be used for designing the switched-capacitor circuits [3]. The filter circuits using switched-capacitor allow very sophisticated, accurate and tunable analog circuits to be manufactured. Many of the circuits proposed the working of only one type of operation [5- 14]. The Switched-Capacitor concept can be used to realize a wide variety of the universal filter that have the advantage of compactness and tenability [5]. Switched capacitor techniques have been developed, so that both digital and analog functions can be integrated on a single silicon chip. Switched-Capacitor filters have the advantage of better accuracy in most cases. Typical center frequency accuracies are normally on the order of about 0. 2% foremost Switched-Capacitor ICs, and worst-case numbers range from 0. 4% to 1. 5% (assuming, of course, that an accurate clock is provided)[6]. This paper proposes a third-order switched-capacitor (SC) Tunable Bandwidth filter with Multifunction Signal. This filter has been studied for different values of Center Frequencies f_0 and Q=1.

2. Basic Switching operation:

The operation of the switched-capacitor can be explained with the help of following circuit diagram:-

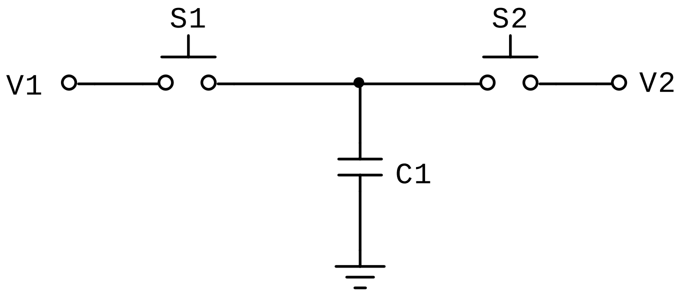

Figure 1: Circuit diagram for operation of the switched-capacitor.

Since the charge q on a capacitor C_1 is given by

$$q = C1V$$

Whereas, V is the voltage across the capacitor C_s. Therefore, when S_2 closes with S_1 open, then S_1 closes with S_2 open a charge q is transferred from V_2 to V_1 with

$$\Delta q = C1\,(V2 - V1)$$

If this switching process is repeated N times in time (t), then the amount of charge transferred per unit time is given by

$$\frac{\Delta q}{\Delta t} = C_1(V_2 - V_1)\frac{N}{\Delta t}$$

L. H. S. is current and number of cycles per unit time is switching frequency.

$$\therefore i = C_1(V_2 - V_1)\, f_{clk}$$

$$\therefore \frac{(V_2 - V_1)}{i} = \frac{1}{C_1 f_{clk}} = R$$

Thus, the switched-capacitor is equivalent a resistor.

3. PROPOSED CIRCUIT CONFIGURATION:

The proposed circuit configuration for Switched-Capacitor Tunable Bandwidth Filter with Multifunction Signal is shown in figure2. The circuit consists of three op–amps (μA 741) with wide identical gain bandwidth product (GB) and three Capacitors with MOSFET, which form Switched-Capacitor. Switched-Capacitor can replace resistors, which was proposed earlier [2]. The input sinusoidal voltage is applied to the inverting terminal of the first op-amp through switched capacitor (SC). The non-inverting terminal is grounded. SC is used in the feedback circuit. The output of the first op-amp is supplied as non-inverting input of the second op-amp. The feed forward input signal is given to the inverting terminal of the second op-amp. SC is used as feedback. The output of the second op-amp is supplied as a non-inverting input of the third op-amp. The inverting terminal is grounded. SC is used as feedback. Low pass function is observed at the output of the third op-amp. The output of the second op-amp gives Band pass function. The High pass function is seen at the inverting input of the first op-amp.

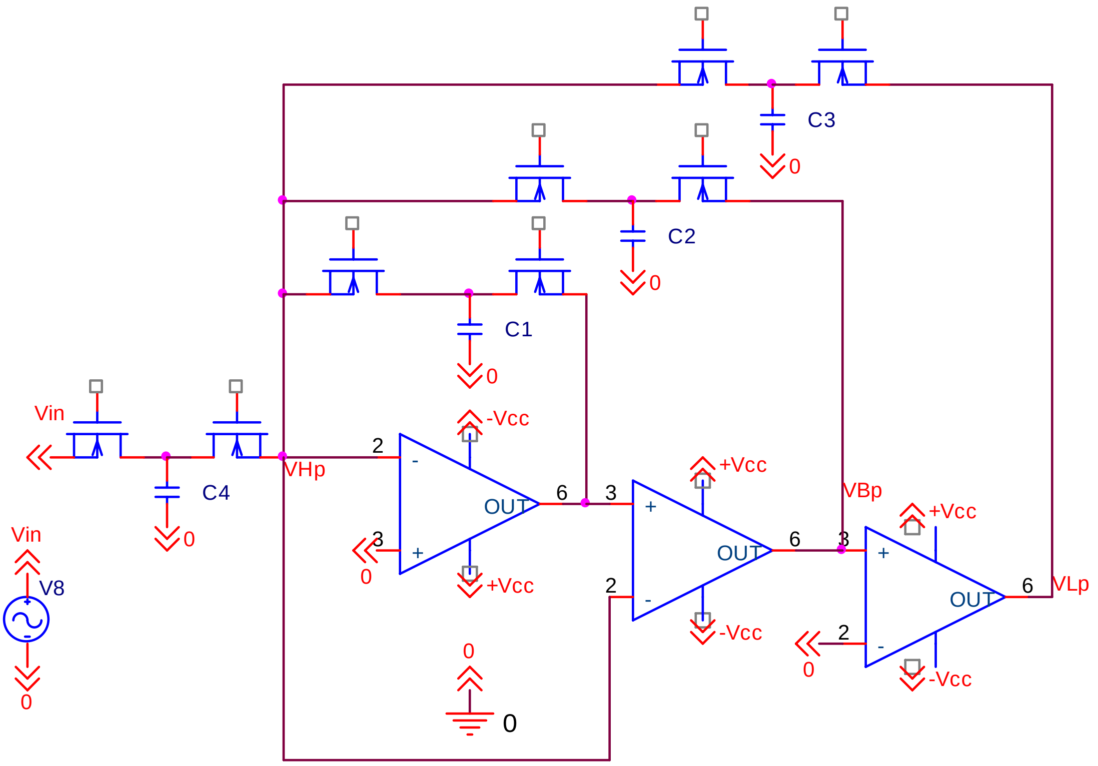

Figure 2: Circuit diagram for Third Order Switched-Capacitor tunable bandwidth filter.

4. CIRCUIT ANALYSIS AND DESIGN EQUATIONS:

Op-amp (μ A741) is an internally compensated op-amp, which is represented by a"Single pole model",

$$A(s) = A_0\omega_0 / (S + \omega_0) \quad (1)$$

Where, A_0 = open loop d. c. gain, ω_0 = open loop -3dB bandwidth, GB = $A_0\,\omega_0$ = gain bandwidth product of op-amplifier.

$$A(s) = A_0\omega_0 / S = GB / S, \quad (2)$$

Where, $S >> \omega_0$

This shows that the op-amplifier is an"integrator". Thus, the Switched-Capacitor Tunable Bandwidth Filter transfer functions at three different terminals are given below. The voltage transfer functions for low pass filter:

$$T_{Lp} = \frac{-\,GB_1GB_2GB_3C_4}{X_1S^3 + X_2S^2 + X_3S + X_4} \quad (3)$$

The voltage transfer functions for band pass filter:

$$T_{Bp} = \frac{-\,SGB_1GB_2C_4}{X_1S^3 + X_2S^2 + X_3S + X_4} \quad (4)$$

The voltage transfer functions for high pass filter:

$$T_{Hp} = \frac{S^3C_4}{X_1S^3 + X_2S^2 + X_3S + X_4} \quad (5)$$

Where

$$X_1 = C_1 + C_2 + C_3 + C_4$$
$$X_2 = GB_1C_1 + GB_2C_2$$
$$X_3 = GB_1GB_2C_2 + GB_2GB_3C_3$$
$$X_4 = GB_1GB_2GB_3C_3$$

The circuit was designed using coefficient matching technique i. e. by comparing these transfer functions with General Third-order transfer functions [10]. The general Third-order transfer function is given by

$$\mathrm{T(S)} = \frac{\alpha_3 S^3 + \alpha_2 S^2 + \alpha_1 S + \alpha_0}{S^3 + \omega_0\left(1 + \frac{1}{Q}\right)S^2 + \omega_0^2\left(1 + \frac{1}{Q}\right)S + \omega_0^3} \quad (6)$$

By comparing (3), (4), and (5) with (6), we get the design equations as

$$C_1 + C_2 + C_3 + C_4 = 1 \quad (7)$$
$$GB_1C_1 + GB_2C_2 = W_0 \{1+1/Q\} \quad (8)$$
$$GB_1GB_2C_2 + GB_2GB_3C_3 = W_0^2 \{1+1/Q \quad (9)$$
$$GB_1GB_2GB_3C_3 = W_0^3 \quad (10)$$

So that Values of C_1, C_2, C_3 and C_4 can be calculated using these equations for different values of f_0 and Q =1 (table1).

Table1: Capacitance values for different values of f_0.

Central Frequency (kHz)	C_1(µf)	C_2(µf)	C_3(f)	C_4(µf)
10	0. 6	63	5. 7n	964
15	52	1. 4	19. 2n	946
20	69	2. 5	45. 6n	928. 5
40	133	9. 8	364. 4n	856. 8
60	192. 6	21. 7	1. 23 µ	784. 5
80	247. 8	37. 9	2. 9 µ	711. 4
100	299	58. 1	5. 7 µ	637. 2

5. SENSITIVITY:

The sensitivities of ω_0 and Q in this Third-order Switched-Capacitor Tunable Bandwidth Filter are as follows.

$$S_{C_1}^{W_0} = -\frac{1}{3}\,C_1$$

$$S_{C_2}^{W_0} = -\frac{1}{3}C_2$$

$$S_{C_3}^{W_0} = -\frac{1}{3}\{C_3 - 1\}$$

$$S_{C_4}^{W_0} = -\frac{1}{3}C_4$$

$$S_{GB_1}^{W_0} = S_{GB_2}^{W_0} = S_{GB_3}^{W_0} = \frac{1}{3}$$

$$S_{C_1}^{Q} = -\frac{1}{3}(1+Q)C_1$$

$$S_{C_2}^{Q} = -(1+Q)C_2\left\{\frac{1}{(C_2+C_3)} - \frac{1}{3}\right\}$$

$$S_{C_3}^{Q} = -(1+Q)\left\{\frac{1}{(C_2+C_3)} - \frac{1}{3} - \frac{2}{3C_3}\right\}$$

$$S_{C_4}^{Q} = -\frac{1}{3}(1+Q)\,C_4$$

$$S_{GB_1}^{Q} = -(1+Q)\left\{\frac{C_2}{C_2+C_3} - \frac{2}{3}\right\}$$

$$S_{GB_2}^{Q} = -\frac{1}{3}(1+Q)$$

$$S_{GB_3}^{Q} = -(1+Q)\left\{\frac{C_3}{C_2+C_3} - \frac{2}{3}\right\}$$

6. EXPERIMENTAL SET UP:

The circuit consists of three op–amps (µA741) with a wide identical gain bandwidth product (GB) and three Capacitors with MOSFET, which form Switched-Capacitor. The circuit performance is studied in different Values of Cut-off frequencies f0 with the circuit merit factor Q= 1. The general operating range of this filter is 10 Hz to 1. 2 MHz. The value of GB (GB1=GB2=GB3) is $(2\pi \times (5.6) \times 10^5$rad/sec). MOSFETs are driven by two non-overlapping clocks. The input voltage of 0. 5mV is applied. The table1 shows the capacitor values for different center frequency f_0.

7. RESULT AND DISCUSSION

The following observations are noticed for low pass, band pass and high pass at corresponding terminals.

7. 1 LOW PASS RESPONSE:

The figure 3 shows the low pass response for different values of f_0.

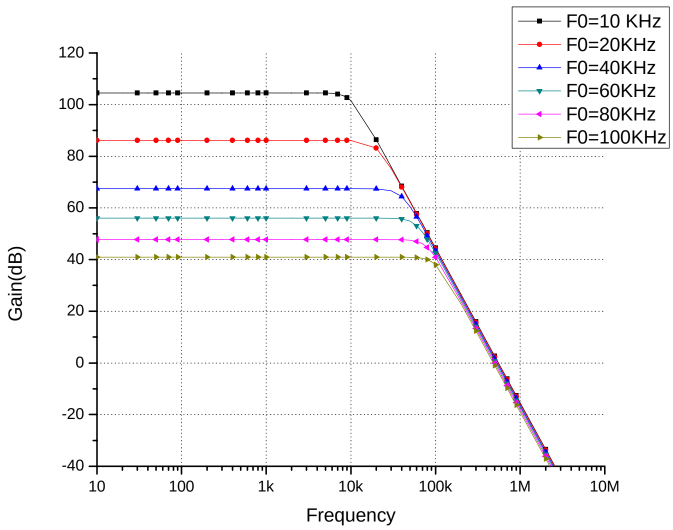

Figure 3: Low pass response for Q=1for different Center frequency f_0.

Table: 2 Low Pass Response Graph (Fig. 3) Analysis

f_0 (kHz)	Max. Pass band gain (dB)	f_{0L} (kHz)	$f_0 \sim f_{0L}$ (kHz)	Gain Roll-off / octave in Stop-band	
				dB/octave	Octave starting at (kHz)
10	104. 5	32	22	18	20
20	86	53	33	18	31
40	67	86	46	18	70
60	56	112	52	18	93
80	48	132	52	18	105
100	40	153	59	17. 8	202

The maximum pass band gain varies between 104. 5dB to 40dB. Also, the gain roll-off per octave varies between 17. 8 to 18dB/octave. But in previous studies maximum pass band gain varies between 105dB to 40dB. Also, the gain roll-off per octave in stop band varies between 18dB/octave to 19dB/octave [6]. The maximum pass band gain decreases with increase in values of f_0. This gives wide pass band. The Gain roll-off values are close to ideal value of 18dB/octave for third order filter. The response shows no overshoot for all the values of f_0.

7. 2 HIGH PASS RESPONSE:-

High pass response of the filter for different values of f_0 is shown in Figure 4

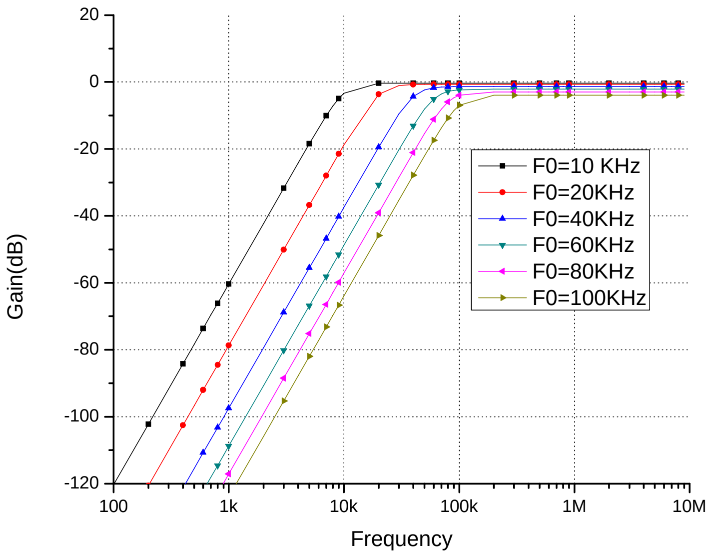

Figure 4: High pass response for Q = 1for different Center frequency f_0.

Table: 3: High Pass Response Graph (Fig. 4) Analysis

f_0 (kHz)	f_{0H} (kHz)	$f_0 \sim f_{0H}$ (kHz)	Gain Roll-off / octave in stop band		Gain Stabilization at pass band	
			dB/octave	Octave starting at (kHz)	(dB)	f_S *(kHz)*
10	10. 4	0. 4	18	7	0	21
20	22	2	18	10	0	35
40	41	1	18	30	0	89
60	61	1	18	47	0	193
80	80. 5	0. 5	18	55	0	226
100	105	5	17. 5	73	-4. 3	266

The Gain roll-off in stop band varies between 17. 5dB/octave to 18dB/octave which is close to the ideal value of 18 dB /octave for third order Switched-Capacitor

Filter. But in previous studies the Gain roll-off in stop band varies between 13 to 14dB/octave [6]. The pass band increases with increase in f_0. The gain gets stabilized almost at 0dB for all values of f_0<80 KHz where as the previous reported configuration shows the gain doesn't stabilized at 0dB for all values of f_0. The response shows no overshoot for all the values of $f_{0.}$ The analysis for the responses are summarizes in the table 3.

7. 3 BAND PASS RESPONSES:

Band pass response of the filter for different values of f_0 is shown in figure 5

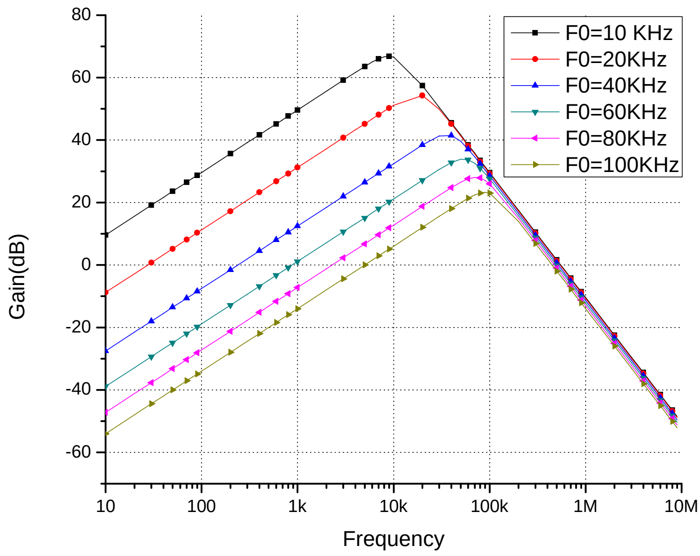

Figure 5: High pass response for Q = 1for different Center frequency f_0.

Table: 4: Band Pass Response Graph (Fig. 5) Analysis

f_0 (kHz)	Max. Pass band gain (dB)	f_1 (kHz)	f_2 (kHz)	BW (kHz)	Gain Roll-off / octave in stop band			
					Leading Part		Trailing Part	
					dB/ octave	Octave starting At (kHz)	dB/ octave	Octave starting at (kHz)
10	66. 7	0. 8	35	34. 2	6	5	12	20
20	53. 8	2. 2	60	57. 8	6	9	12	30
40	41	6. 7	101	94. 3	6	20	12	76
60	33. 6	14	125	111	6	30	12	100
80	27. 7	22	152	130	6	40	12	111
100	23	33	165	132	6	40	12	203

The maximum pass band gain varies between 66. 7dB to 23dB and bandwidth also varies between 34. 2 KHz to 132KHz. But in previous studies, the maximum pass band gain varies between 87dB to 22. 3dB and bandwidth also varies between 17KHz to 30KHz [6]. The maximum pass band gain is 66. 7dB which decreases with increase in central frequency f_0. The bandwidth is increases with increasing in values of f_0. For lower values of f_0, this filter can be used for narrow bandwidth and for higher values of f_0 it can be used for wide bandwidth. There is no shift in the central frequency. It is also observed that the pass band distribution of frequency is symmetric for both sides. The gain roll-off/octave in leading and trailing part of the response is same. The circuit works better band pass response for f_0 >20 KHz.

8. CONCLUSIONS:

A realization of Third-Order Switched-Capacitor Tunable Bandwidth Filter with Multifunction Signal for different Center Frequencies (f_0) has been proposed. The three filter functions low pass, high pass and band pass at different terminals works with satisfied results. The filter circuit can be used for both narrow as well as wide bandwidth, so this circuit works for tunable bandwidth. The gain roll-off of this circuit is close to the ideal value of 18 dB/octave (40dB/decade) for third order filter thus the circuit shows better response for f_0 >20 KHz. Also, the Stabilization of gain for High pass filter function can be achieved at0dB for f_0<60KHz. The Low pass filter function works practically only for higher center frequencies f_0.

9. REFERENCES:

[1] G. N. Shinde and P. B. Patil,”Study of active-R second order filter using feedback of non-inverting terminal,”Bulletin of Pure and Applied Sciences, Vol. 21 D, No. 1, pp. 23-30, 2002.

[2] M. Ghausi,”Analog active filters,”IEEE Transactions on Circuits and Systems, Vol. 31, pp. 13-31, 1984.

[3] William R. Grise, Applications of Switched capacitor circuits in active filters and Instrunental Amplifiers, (3), 1523-26, 1999

[4] G. N. Shinde, P. B. Patil, A. B. Kadam and P. R. Mirkute,”Active-R biquadratic filter using positive feedforwardsignal,”BRI’S JAST, Vol. 5(I and II), pp. 7-15, 2002.

[5] G. N. Shide and S. R. Bhagat“tunble bandwidth third order switched-capacitor with multiple feedbacks filter for different center frequencies”Engineering 2, 179-183, 2010

[6] Jinguang Jiang and Yaonan Wang,”Design of a tunable frequency CMOS fully differential fourth order Chebyshev filter”, Microelectronics Journal, 37, 2006.

[7] G. J. Yu, C. Y. Huang, J. J. Chen and B. D. Liu,”Designof current mode square root domain bandpass filter withreduced voltage,”Analog-Integrated Circuit and Signal Processing, Vol. 44, pp. 239-250, 2005.

[8] R. Senani and S. S. Gupta,”Low universal filter using only current followers as active elements,”International Journal of Electronics and Communication, Vol. 60, pp. 251-256, 2006.

[9] J. G. Jiang and Y. N. Wang,”Design of a tunable frequency CMOS fully differential fourth order chebyshe filter”, Microelectronics Journal, Vol. 37, pp. 84-90, 2006.

[10] Srinivasan,”Synthesis of transfer functions using the operational amplifier pole”, Int. J. Electronics, vol. 40(1), 5-13, 1976.

[11] William R. Grise”Applications of Switched capacitor circuits in active filters and Instrumental Amplifiers”VOL-3, No. 3, 1523-26, 1999.

[12] Jinguang Jiang and Yaonan Wang,”Design of a tunable frequency CMOS fully differential fourth order Chebyshev filter”, Microelectronics Journal, VOL-37, 84-90, 2006

[13] G. N. Shinde and S. R. Bhagat,”Feed Forward Third Order Switched Capacitor Filter for different circuit merit factor Q values”, Archives of Applied Science Research, Vol 2, No 1, 277-285, 2010

[14] Yonghyun Shim and Mina Rais-Zaden“A high-performance continuously Tunable Band pass Filter”IEEE Transactions on microwave theory and Technique, vol. -60, No. 8, 2441-2446, 2012.