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# A Multifunction Filter for Instrumentation Applications

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**ABSTRACT**

A multifunction active filter which can realise low pass, high pass, band pass, notch and all-pass functions has been reported. The circuit uses six operational amplifiers and is similar to OTA and CCII based earlier realisations. The performance of the circuits has been verified experimentally.

## 1. Introduction

The active filters are widely used in instrumentation and communication systems [1]. There are basically five types of filters viz-low pass, high pass, notch, band pass and all-pass. In the literature the term multifunction/universal active filter has been used for a circuit which can realise high pass, low pass and band pass or notch filter but more appropriately the word universal active filter stands for a circuit which can realise all five types of filters mentioned above. Using current conveyors and operational transconductance amplifier (OTA) the universal active filter realising all types of filters is available [2-3]. In this paper an operational amplifier version similar to [2] and [3] is reported. As operational amplifier is easily available element this circuit is most suited for discrete applications in industries and research institutions. The circuit can also be integrated except capacitors similar to UAF [4].

## 2. Proposed Configuration

The general proposed configuration is shown in Fig.1. It has the following voltage transfer function

$$\frac{V_o}{V_i} = \frac{\dfrac{Z_6Z_7Z_9}{Z_1Z_8Z_{10}} + \dfrac{Z_6Z_9}{Z_3Z_{10}} + \dfrac{Z_6}{Z_5}}{\left(1 + \dfrac{Z_6Z_7Z_9}{Z_2Z_8Z_{10}} + \dfrac{Z_6Z_9}{Z_4Z_{10}}\right)} \tag{1}$$

On substituting $Z_1 = R_1$, $Z_2 = R_2$, $Z_3 = R_3$,

$Z_4 = R_4$, $Z_5 = R_5$, $Z_6 = R_6$,

$Z_7 = 1/sC_7$, $Z_8 = R_8$, $Z_9 = 1/sC_9$,

$Z_{10} = R_{10,}$

and solving one gets

$$\frac{V_O}{V_I} = \frac{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_5} - sC_7 \dfrac{R_8}{R_3} + \dfrac{1}{R_1}}{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_6} + sC_7 \dfrac{R_8}{R_4} + \dfrac{1}{R_2}} \tag{2}$$

The actual circuit is shown in Fig.2. It realises various filters for following resistance values.

(i) LOW PASS FILTER: - $R_3 = R_5 = \infty$

$$\frac{V_o}{V_i} = \frac{1}{s^2 C_7 C_9 \dfrac{R_8 R_{10} R_1}{R_6} + sC_7 \dfrac{R_8 R_1}{R_4} + \dfrac{R_1}{R_2}} \tag{3}$$

(ii) HIGH PASS FILTER: - $R_1 = R_3 = \infty$

$$\frac{V_O}{V_I} = \frac{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_5}}{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_6} + sC_7 \dfrac{R_8}{R_4} + \dfrac{1}{R_2}} \tag{4}$$

(iii) BAND PASS FILTER: - $R_1 = R_5 = \infty$

$$\frac{V_O}{V_I} = \frac{-s\ C_7 \dfrac{R_8}{R_3}}{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_6} + sC_7 \dfrac{R_8}{R_4} + \dfrac{1}{R_2}} \tag{5}$$

(iv) NOTCH FILTER: - $R_3 = \infty$

$$\frac{V_O}{V_I} = \frac{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_5} + \dfrac{1}{R_1}}{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_6} + sC_7 \dfrac{R_8}{R_4} + \dfrac{1}{R_2}} \tag{6}$$

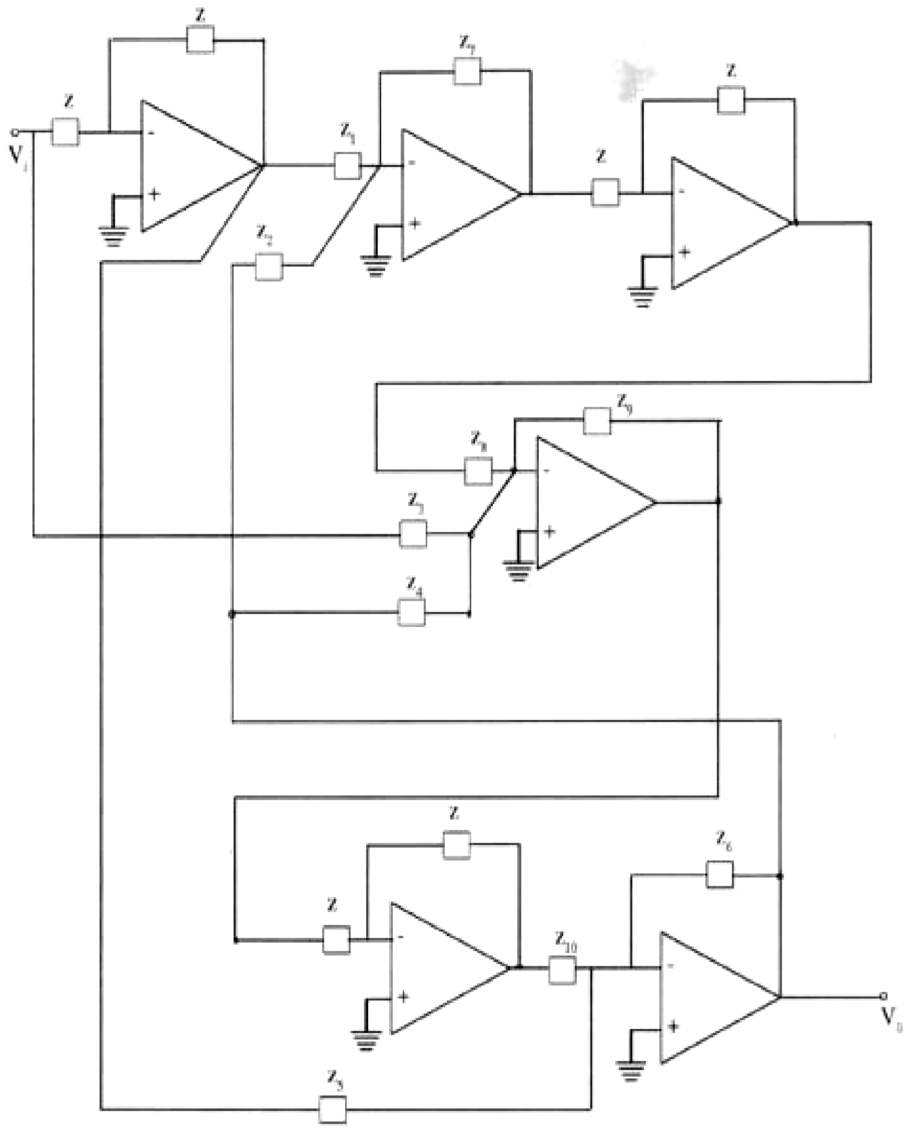


Fig.1 General Configuration

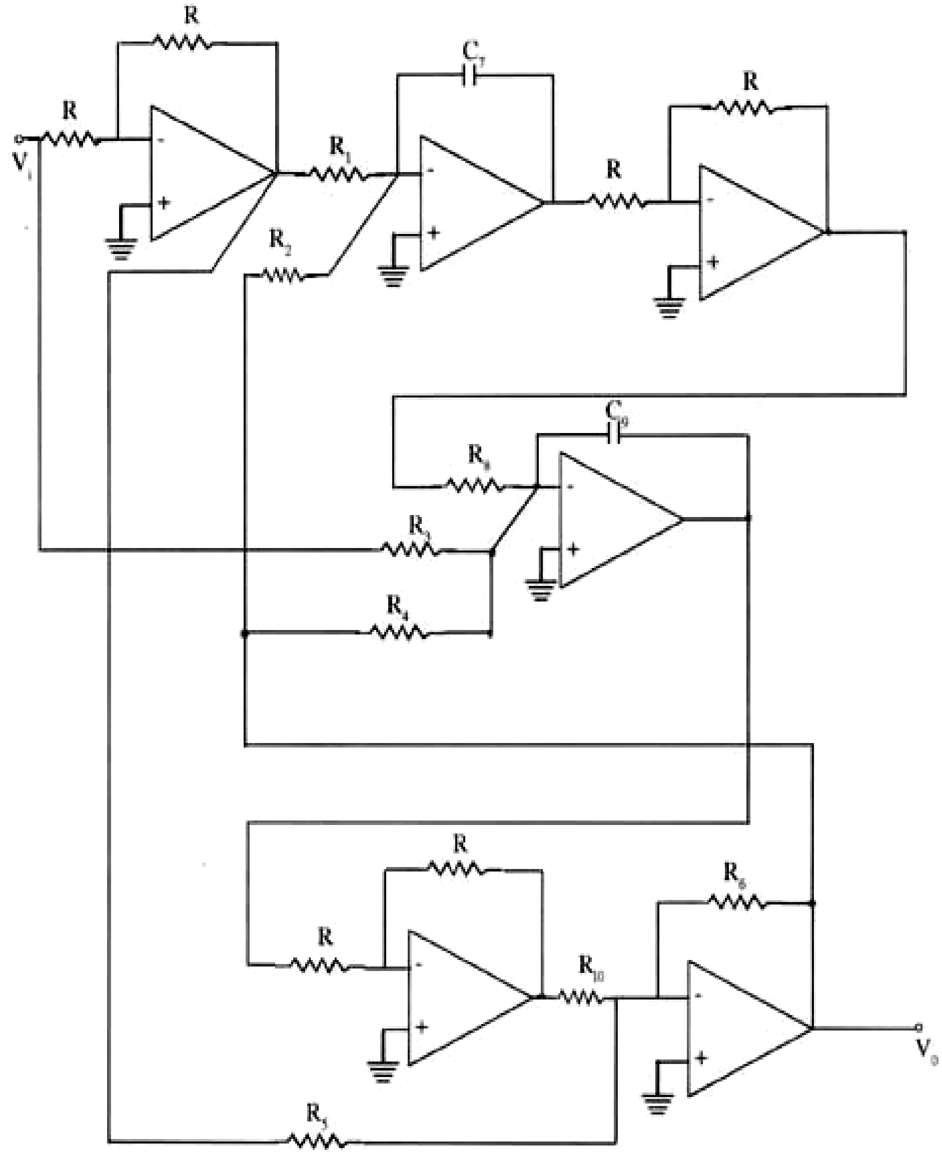


Fig .2 Universal Active filter using OP.Amp.

The notch frequency is controllable through single resistance $R_{10}$ and quality factor can be controlled through $R_4$, which makes it a novel realisation.

(v) ALL PASS FILTER: - $R_1 = R_2$, $R_3 = R_4$ and $R_5 = R_6$

$$\frac{V_O}{V_I} = \frac{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_5} - sC_7 \dfrac{R_8}{R_3} + \dfrac{1}{R_1}}{s^2 C_7 C_9 \dfrac{R_8 R_{10}}{R_5} + sC_7 \dfrac{R_8}{R_3} + \dfrac{1}{R_1}} \tag{7}$$

The phase shift of all pass filter is adjustable through single resistance $R_{10}$.

As compared to similar realisations using OTA [2] and current conveyors [3] the present circuit requires less number of active elements and among the operational amplifier circuits [1, 5-7] it is a unique realisation.

## 3. Experimental Results

The proposed configuration was tested for band pass filter and notch filter for following component values

**Band Pass Filter :-**

$C_7 = C_9 = 0.01\ \mu f$, $R_2=R_6=R_8=R_{10}=10k\Omega$

$R_3=R_4=1K\Omega, 5K\Omega, 10K\Omega$ and $20K\Omega$

**Notch Filter :-**

$C_7 = C_9 = 0.01\ \mu f$, $R_1=R_2=R_5=R_6=R_8=R_{10}=10k\Omega$

$R_4=1K\Omega$, $5K\Omega, 10K\Omega$ and $20K\Omega$

The practical results support the theory as given by four different curves of band pass filter shown in Fig 3&4. To obtain good results one must use precision resistance and capacitances and signal oscillator used in experiment must be a low distortion oscillator. IC CA-3140 was used in the experiments and the same was operated using 12V positive and negative power supplies.

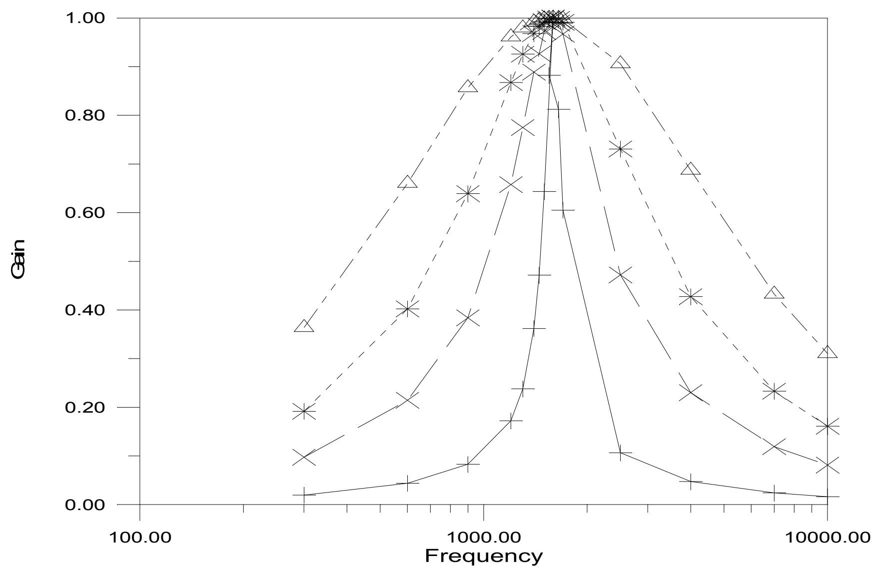


**Fig. 3. Band Pass Filter Response**

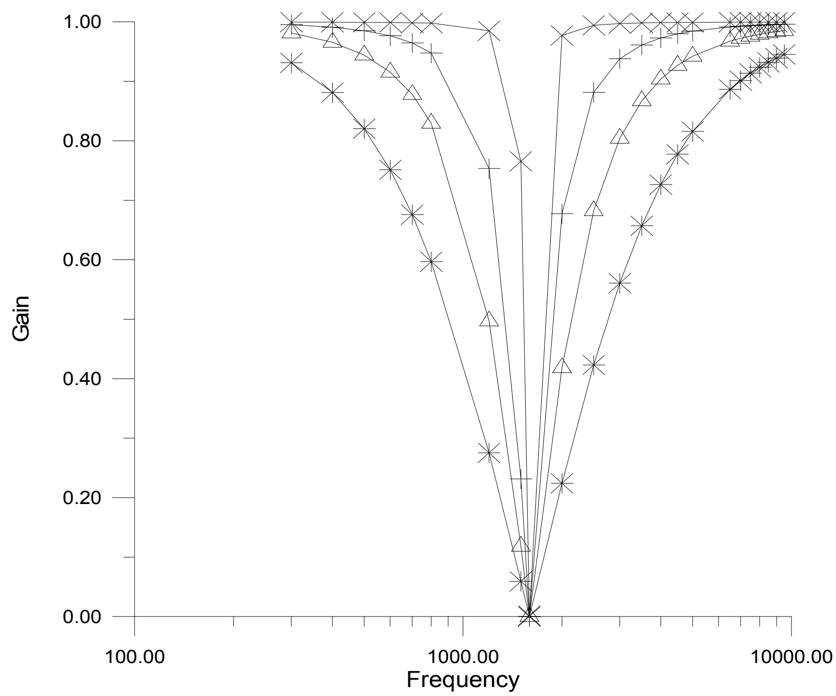


**Fig. 4. Notch Filter Response**

## 4. Conclusions

A simple and unique type of operational amplifier based universal active filter has been reported. The circuit has independent control of cutoff rate, and notch frequency in case of band pass and notch filters. The circuit is ideal for laboratory and industrial applications as it can be realized with available low cost operational amplifiers like LM-741 or CA-3140.

## REFERENCES


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