CHAPTER : IV

STUDY OF A NEW ACTIVE R FILTER CIRCUIT

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4.1 INTRODUCTION :-

The active filters are the filter circuits which contains active devices and passive components. The use of inductor is usually avoided in this case because of the lossess associated with and large size.

This is also true for integrated circuit variations. Hence nowadays the most circuit use R and C which are called active 'RC' filters.

More attention is being given to the production of monolithic linear circuits to minimize the cost of a circuit and to increase the circuit density. Thus it is concluded that the size of the circuit should be as small as possible.

Basically in integrated circuit capacitor requires more area than a resistor. Due to this reason any filter circuit without external capacitor would have minimum size. Such circuits are called "active R" Filters.

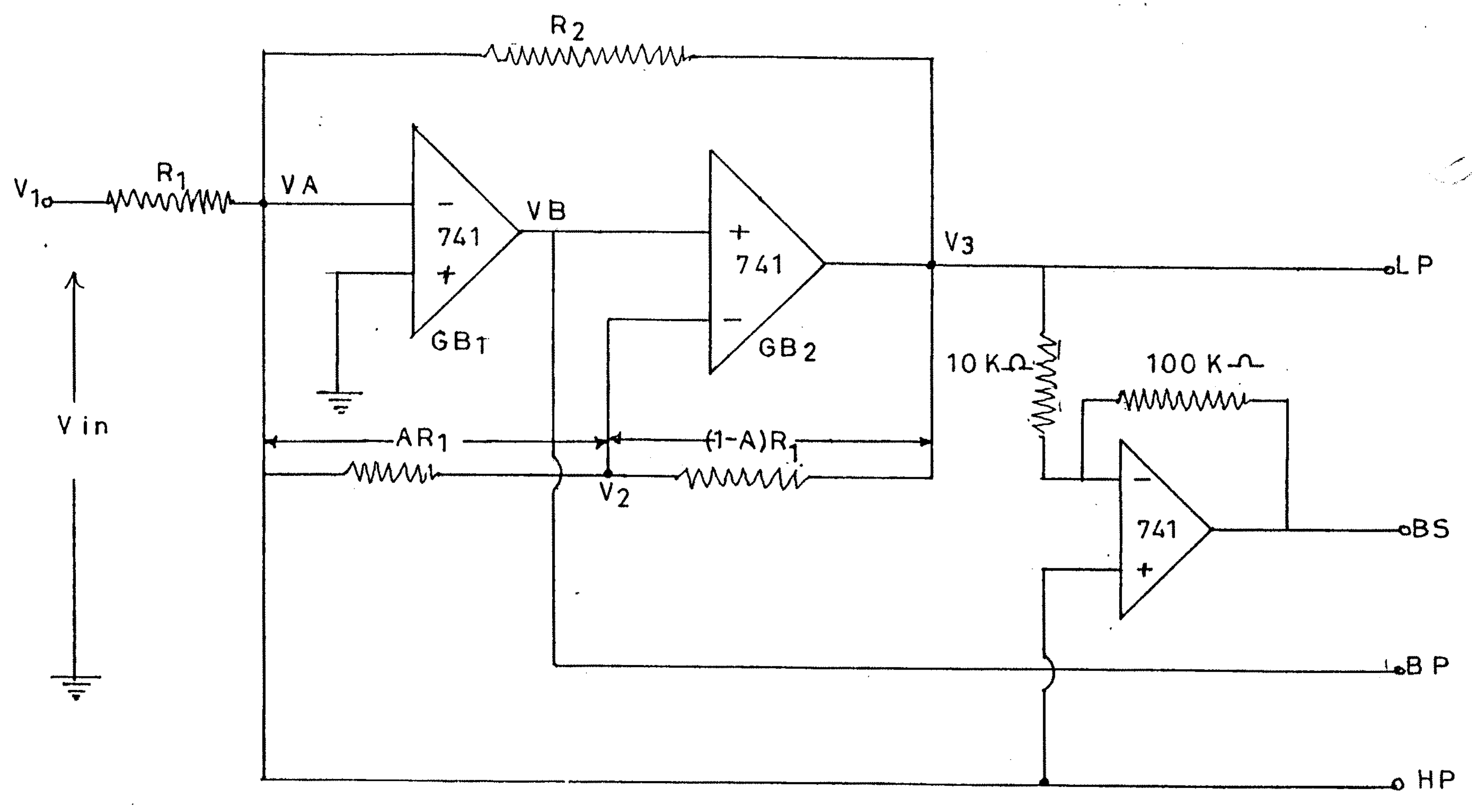
The filter circuits have become an integral part of many electronic systems for a vary long time. They have been used for different applications as mentioned earlier. With the availability of high performance operational amplifiers the trend was shifted to design and use of active filters with OP-AMP as the main active device.

The operational amplifier frequency response curve is almost similar to the response of low pass filter. This enables one to consider the operational amplifier as a single pole integrator. In other words inherent parasitic capacitance associated with the device is utilized in designing filter circuits with resistor as only external passive element, and hence these are active 'R' filter circuits.

In this dissertation theory, design and the response of a new Active R filter circuit is discussed.

4.2 CIRCUIT DIAGRAM :-

Fig (4.1) shows a new Active R filter configuration. It is seen that all the four filter functions are provided at various output terminals. It is also multiple feedback circuit. The resistance 'R_3' is tapped to the control and resistance 'R_2' provides the feedback.



(Fig.4.1) NEW ACTIVE R FILTER CIRCUIT

The tapping point variation will control the gain of both the operational amplifiers and the frequency response of the overall circuit.

The low pass and high pass action, when combined by the third operational amplifier, provides the band stop action.

4.3 CIRCUIT ANALYSIS :-

We know that the operational amplifier can be considered as a single pole integrator. Mathematically therefore, the operational amplifier can be represented by

$$A(s) = \frac{A_o \omega_o}{S + \omega_0} \quad .....(4.1)$$

Where A_0 is open loop d.c. gain and ω_o is the open loop - 3 dB bandwidth in rad/sec.

This can also be written as -

$$A(s) = \frac{GB}{S} \quad ......(4.2)$$

Where, $A_o \omega_o$ = GB, represents the gain bandwidth of the operational amplifier.

Most of the operational amplifiers are internally compensated and ω_o is of the order of 25 - 100 rad/sec.

Using equation (4.2) various transfer functions of the circuit can be obtained as shown below -

1. <u>For Low Pass Filter :-</u>

$$T_{(LP)} = \frac{V_3}{V_1} = \frac{-\left(\frac{1}{R_1}\right)\left[(1-A)\ GB_2.S + GB_1.GB_2\right]}{S^2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + GB_2.S\left(\frac{A}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + GB_1.\ GB_2\left(\frac{1}{R_2} + \frac{1}{R_3}\right)} \quad .....(4.3)$$

2. <u>For high pass filter</u>

$$T_{HP} = \frac{V_A}{V_1} = \frac{\frac{1}{R_1}\left(S^2 + AGB_2\ .\ S\right)}{S^2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + S.GB_2\left(\frac{A}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + GB_1\ .\ GB_2\left(\frac{1}{R_2} + \frac{1}{R_3}\right)} \quad ....(4.4)$$

3. <u>For Band Pass Filter :-</u>

$$T_{BP} = \frac{V_B}{V_1} = \frac{\left(S^2 + AGB_2.\ S\right)\left[\frac{-S}{G\ B_1 R_1}\right]}{S^2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + GB_2.S\left(\frac{A}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + GB_1.\ GB_2\left(\frac{1}{R_2} + \frac{1}{R_3}\right)} \quad ....(4.5)$$

4.4 DESIGN CONSIDERATION :-

The design of a new active - R circuit is quite straight forward. In this procedure we can compare the transfer functions with general second order transfer function given by,

$$T(S) = \frac{\alpha_2 S^2 + \alpha_1 . S + \alpha_0}{S^2 + \left(\frac{\omega_o}{Q}\right) S + \omega_o^2} \quad .....(4.6)$$

It is notice that the resistance R_3 control the pole frequency ' ω_o' while resistance R_1 control the Q value.

Comparing the various coefficients in equation (4.6) with transfer functons. Following equations are obtained.

$$\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = 1 \quad ....(4.7)$$

$$GB_2 \left(\frac{A}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{\omega_o}{Q} \quad ....(4.8)$$

$$GB_1 . GB_2 \left(\frac{1}{R_2} + \frac{1}{R_3}\right) = \omega_o^2 \quad .....(4.9)$$

Where the gain bandwidth products of both operational amlifiers GB_1 and GB_2 are equal.

Notice that impedance scaling of the R_1, R_2, R_3 may be used to obtain more practical values of resistances. By multiplying these by the impedance scale factor 100 we get the practical values of resistances.

For practical realization the value of R_3 should be positive.

Hence, if f_o and resistances are assumed an upper limit is set on the value of Q.

Re-arranging the equation (4.8) with

$$GB_1 = GB_2 = GB$$

$$Q < \frac{1}{2} \sqrt{\frac{R_1}{A}} \quad .....(4.10)$$

4.5 SENSITIVITY CONSIDERATION :-

The various sensitivites for this new circuit are calculated using standard formulae.

1. $$S^{w_o}_{R_1} = -\frac{1}{2} \cdot -\frac{GB_2}{GB_1}$$

2. $$S^{w_o}_{R_2} = 2Q^2 \cdot \frac{GB_2}{GB_1} \left[\frac{R_1 + R_3}{R_1 \; R_3} - 1 \right]$$

3. $$S^{w_o}_{R_3} = \frac{-ZQ^2}{R_3} \cdot \frac{GB_2}{GB_1}$$

4. $$S^{w_o}_{GB_1} = S^{w_o}_{GB_2} = -1$$

5. $$S^{Q}_{R_1} = \frac{1}{2} \cdot \frac{R_1}{Q^2} + \frac{GB_1}{GB_2}$$

6. $$S^{Q}_{R_2} = \frac{GB_1}{GB_2} \cdot \frac{2R_3}{(R_1R_3 - R_1 - R_3)}$$

7. $$S^{Q}_{R_3} = \frac{GB_1}{GB_2} \cdot \frac{2AR\ \ 2}{(R_1R_2 - R_1 - R_2)}$$

8. $$S^{Q}_{GB_1} = \frac{1}{2}$$

9. $$S^{Q}_{GB_2} = -1$$

It is found that all passive sensitivities are less than one in magnitude but active sensitivities are half in magnitude.