The Design of Analog Active Filter with Different Component Value using Genetic Algorithm

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ABSTRACT
The basic purpose in active filters design is to calculate of filter transfer function providing desired features and is to find component values. By using of classical calculation methods in active filters component values calculations cause over time and process load and a different design with found same component value cannot be done. In this study, the reaching of analog active filter amplitude response that provides desired features with different component value that is found by helping of Genetic Algorithm (GA) is provided. With this work, the circuit design by using of different component values at different stages was enabled. In this way, unlike the studies at literature, the same selection imperative of component values have been eliminated to provide easy calculation and this offers easier circuit design possibility for users. In addition; with helping of implemented study, the increasing process load depending on filter degree is eliminated. To reach desired filter characteristic, obtained amplitude response from the used approach methods and desired amplitude response were compared and satisfactory results were observed.

General Terms
Evolution Calculation, Signal Processing, Circuit and System Design

Keywords
Genetic algorithms, Analog circuit design, Active filter,

1. INTRODUCTION
The system used to obtain output signal for desired features is called as filter. The implemented filters that use circuit equipments are analog filters. The system which is used to eliminate negative effects of inductance in an analog filter is also called as active filters.

Active analog filters are made up of many different circuit components. All circuit component values must be known to solve an analog filter. The following way designing active analog filter is generally in the form of determining component value inspired from well known circuit model [1]. In the methods, component choices are generally made from standard series values and this situation makes more difficult the circuit design for different component value. However, implementing filter transfer function providing features with different component values is desired. Because of the failure of finding different component value of classical calculation methods, different methods have been developed such as Tabu Search Algorithm (TSA), Genetic Algorithm (GA), Ant Colony Optimization algorithm (ACO), Simulated Annealing (SA).

Ning and et al. used SA methods to optimize circuit dimension [2]. While Jayaraman ve Rutenbar used to SA for applications of cell-placement and floor-planning which are described as discrete problem [3], Wong and Liu, Gupta and et al. have used to SA for designing of non discrete FR power amplifier [4, 5]. By using of TSA, many studies have been done for optimum circuit dimension and placement of component in the analog circuit [6, 7, 8, 9, 10, 11]. Kuntz and et al. implemented circuit design by using of ACO algorithm [12]. However, determination of component values with ACO algorithm was implemented by Kalinli in the analog circuit design [13].

In literature, there are many studies about the usage of GA in analog circuit design. Krusiskamp and Leenaerts suggested GA by using of Op-Amp in the analog circuit design [14]. Paulino and et al. recommended using of GA to solve non-convex problems [15]. Grimbleby also used GA for optimization approach based on simulation [16]. Many studies about designing of active and passive filter and for choice of component value by using of GA have been done by Horrocks and et al [17, 18, 19, 20]. Horrocks improved the design process to choose standard series values in the calculation of component values of analog filter design. However, this method doesn’t succeed in providing desired features by using of different component values. Thus, the filter design that provides desired features with different component values is required.

In this study, design of the filter transfer function providing desired feature was implemented with adjusted component instead of standard resistance. Thus, the obstacles limiting design of the user were removed and the program that will provide fast and easy design process were developed.

2. ACTIVE FILTERS USING OP-AMP
At study, well known Sallen-Key filter circuit was used and it was shown at Fig 1. This circuit is a bandpass active filter using Butterworth approach. The transfer function for this stage has been shown at equation 1. The different filters which theirs order has been increased can be obtained by connecting circuit in Fig 1 cascade.

$$H_{c,P}(s)=\frac{\frac{K.s}{R_1C_1}}{s^2+\left[\frac{1}{R_1C_1}+\frac{1}{R_3C_1}+\frac{1}{R_3C_2}+\frac{(1-K)}{R_1C_1}\right].s+\frac{R_1+R_2}{R_1R_2R_3C_1C_2}} \quad (1)$$

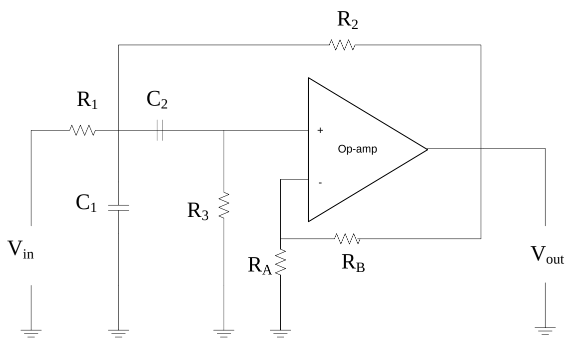


Fig 1: Bandpass active filter stage

The constant (K) in equation 1 can be defined as,

$$K=1+(R_B/R_A) \quad (2)$$

Some acceptances should be in solution of circuit with traditional methods. These are R1=R2=R3 and C1=C2. When these values replace at transfer function at equation 1, new transfer function is as equation 3.

$$H_{c,P}(s)=\frac{\frac{K.s}{RC}}{s^2+\left[\frac{(4-K)}{RC}\right].s+\frac{2}{R^2C^2}} \quad (3)$$

The coefficients that depend on R and C at obtained transfer function are constant. Instead of these values, coefficients such as a and b are used to simplify of circuit solution. The obtained transfer function has been shown at equation 4.

$$H_{a,H}(s)=\frac{a_1.s}{s^2+b_1.s+b_2} \quad (4)$$

The equivalents of terms at denominator after match are as below.

$$b_1=(4-K)/RC \quad (5)$$

$$b_2=2/R^2C^2 \quad (6)$$

If the equations are solved, the following results are obtained.

$$R=\sqrt{2/b_2C^2} \quad (7)$$

$$K=4-\sqrt{2b_1^2/b_2} \quad (8)$$

$$R_B/R_A=3-\sqrt{2b_1^2/b_2} \quad (9)$$

The overall gain of active filter must be calculated. These processes are more difficult and complex than the processes in lowpass or highpass filters because of bandpass centre frequency (ω_0) should be adjusted for the gain calibration. The gain adjustment factor (GAF) for each stage is then the ratio of the two numerator constants as shown in Equation 8. The total gain adjustment is then the product of this stage gain adjustments.

$$GAF=\prod_{i=1}^{m}K_i/(a_{1i}R_iC_i) \quad (10)$$

where m is stage number. As can be seen, there are more complex processes in the circuit solutions done with traditional methods. The emerged problem at classic circuit solution is the making of some initial acceptances. Circuit solution gets easy with consequence of these acceptances, but component values must be same. The designers who have different circuit components have difficulty at circuit design with these methods. With this work, the necessity of doing initial acceptances was eliminated and necessary process load for calculation of component values at circuit was removed. With this application, different component values providing same transfer function can be obtained.

New methods to reach the result with different component value at literature have been improved. The calculations done with using heuristic methods give successful results to reach the conclusion with different component value. GA, one of the alternative optimization methods, having parameters has been used many application areas.

3. OPTIMIZATION ALGORITHM USING GENETIC ALGORITHM

GA, one of the methods of the heuristic calculation is based on principle protection of the best (conversation of optimum). When there are any data about solution, initial population is obtained from that data. At used GA program, chromosomes are coded by real value not binary codes. Chromosomes in the creating population are used in fitness function, different from problem to problem, to measure the fitness. The fitness function for improved method is defined as a function to minimize difference between the obtained amplitude response samples by using of chromosome at GA and amplitude response samples which provide desired features.

$$F_{firness}=\min\sum_{i=1}^{M}\left|\begin{array}{l}\text{(i.sample from desired amplitude response)}\\ \text{-(i.sample from found amplitude response)}\end{array}\right| \quad (11)$$

i=1,….M where M sample number.

Due to the fitness value, for creating next generation, chromosome in the population is reproduced and crossed and mutated if necessary.

The calculated copy numbers of each chromosome determine which chromosome will be used at reselection, crossing or mutation operations. Chromosome having higher possibility to be selected is crossed more times and it is in the next generation more times. Chromosome having less possibility is rarely taking places in the next generation or maybe it is no in that.

This process is continued until value of desired convergence or reaches max. generation number [21]. The GA evolution cycle was demonstrated at Fig 2.

4. SIMULATION RESULTS

In this study, the component values create the initial population of GA and these values are calculated helping of improved programme. For this aim, the programme was run changing of parameters of circuit and GA and the different results were obtained.

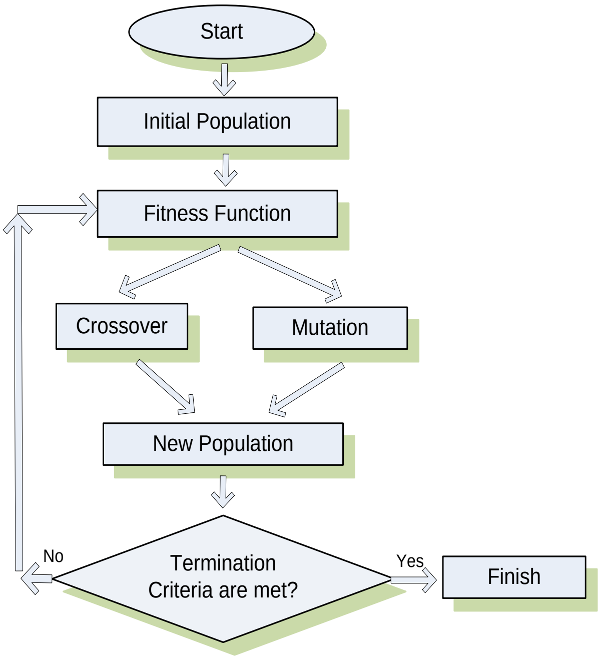


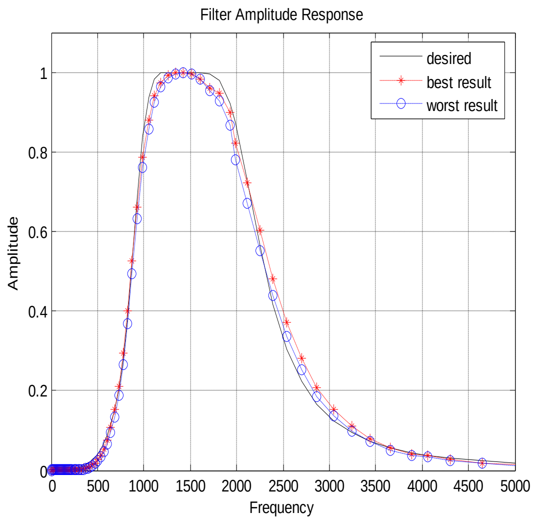
Fig 2: The GA evolution cycle

The simulation applications were done for same filter type and same conditions to show performance of the proposed study. The initial conditions were shown in Table 1.

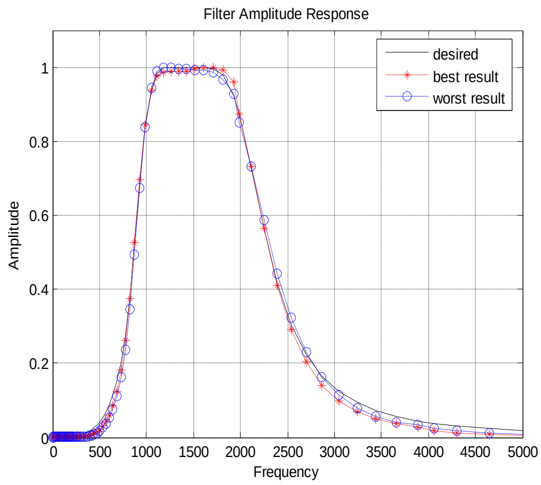
Table 1. Initial conditions

Filter type	BP
Passband edges F_{p1}	1000 Hz
Passband edges F_{p2}	2000 Hz
Stopband edges F_{s1}	500 Hz
Stopband edges F_{s2}	4000 Hz
Pass band ripple	1.5 dB
Stop band ripple	28 dB

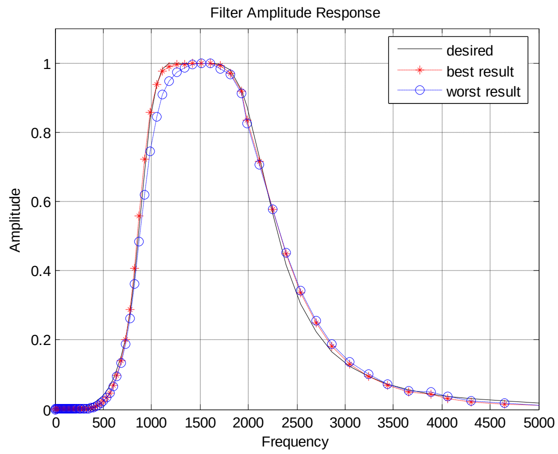
The programme results for different generation number were shown at Fig 3.



a) Generation number: 100



b) Generation number: 250

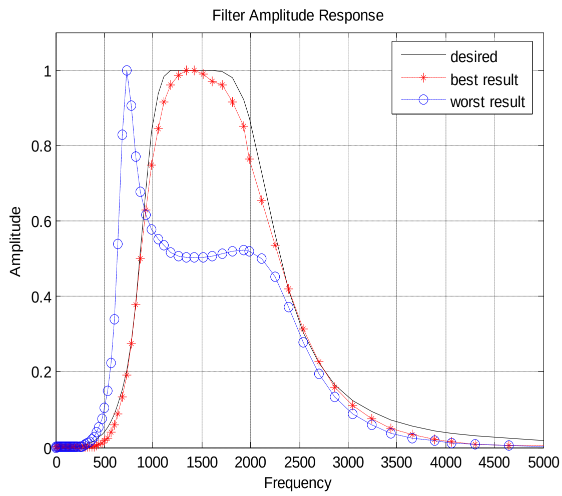


c) Generation number: 500

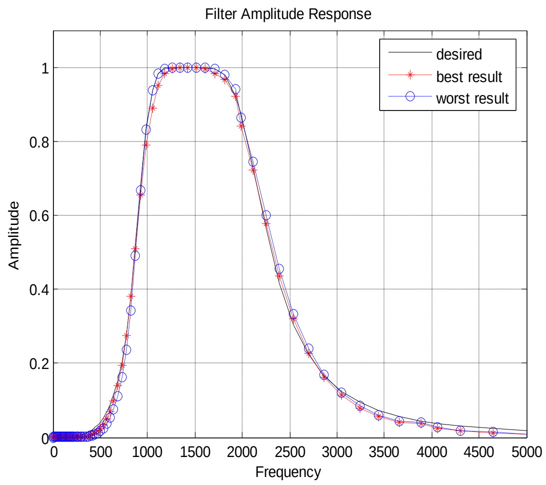
Fig 3: Simulation results for different generation number (a, b, c)

From the Fig 3, it is seen that GA obtained amplitude response for the generation number 250 approximately.

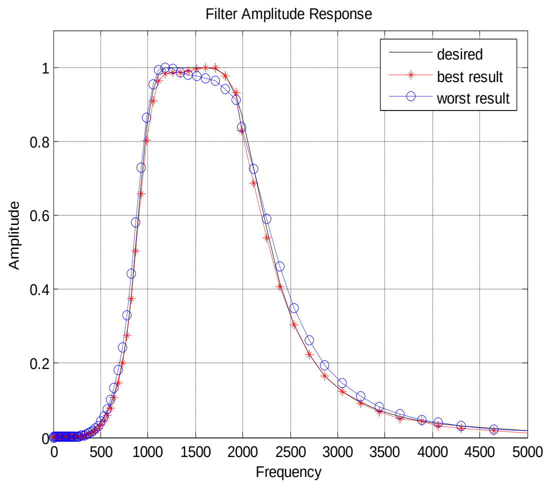
The programme results for different resistance values are shown in Fig 4 and data are given in Table 2.



a) Resistance between 1Ω and 0.9 kΩ



(b) Resistance between 1 kΩ and 9.9 kΩ



(c) Resistance between 10 kΩ and 99.9 kΩ

Fig 4: Simulation results for different resistance values

Table 2. Results for different resistance values

Stage no (m)	Between 1Ω – 0.9 kΩ			Between 0.9 kΩ – 9.9 kΩ			Between 10 kΩ – 99.9 kΩ			Commands results
	R1	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1=R2=R3(kΩ)**
1	0.0183	0.0553	0.1015	4.4414	2.0209	1.5155	68.0069	36.4633	33.6354	22.68
2	0.1871	0.4801	0.5664	8.8508	9.0098	2.1522	16.1161	12.9521	13.0122	11.17
3	0.7324	0.3660	0.0280	9.3845	9.5990	8.7534	15.8656	55.5357	18.1917	15.92

In the circuit design implemented by taking component value equally, the design process is impossible with different component values that the user have. This problem has been removed with helping of improved method.

In Fig 4.(a), it has been found R1=0.02, R2=0.06, R3=0.1 instead of R1=R2=R3=22.7 for the first stage, R1=0.2, R2=0.5, R3=0.6 instead of R1=R2=R3=11.2 for the second stage, R1=0.7, R2=0.4, R3=0.03 instead of R1=R2=R3=15.9 for the third stage and the result close to the amplitude response that will provide desired conditions was obtained. In Fig 4.(b), it has been found R1=4.4, R2=2, R3=1.5 instead of R1=R2=R3=22.7 for the first stage, R1=8.9, R2=9, R3=2.2 instead of R1=R2=R3=11.2 for the second stage, R1=9.4, R2=9.6, R3=8.8 instead of R1=R2=R3=15.9 for the third stage and the result close to the amplitude response that will provide desired conditions was obtained. In Fig 4.(c), it has been found R1=68, R2=36.5, R3=33.6 instead of R1=R2=R3=22.7 for the first stage, R1=16.1, R2=13, R3=13 instead of R1=R2=R3=11.2 for the second stage, R1=15.9, R2=55.5, R3=18.2 instead of R1=R2=R3=15.9 for the third stage and the result close to the amplitude response that will provide desired condition was obtained.

According the resistance values in between 10 kΩ and 99.9 kΩ, bandpass active filter circuit with 3 stage-6th order was illustrated at Fig 5 for C=0.01 µF and R_A=10 kΩ

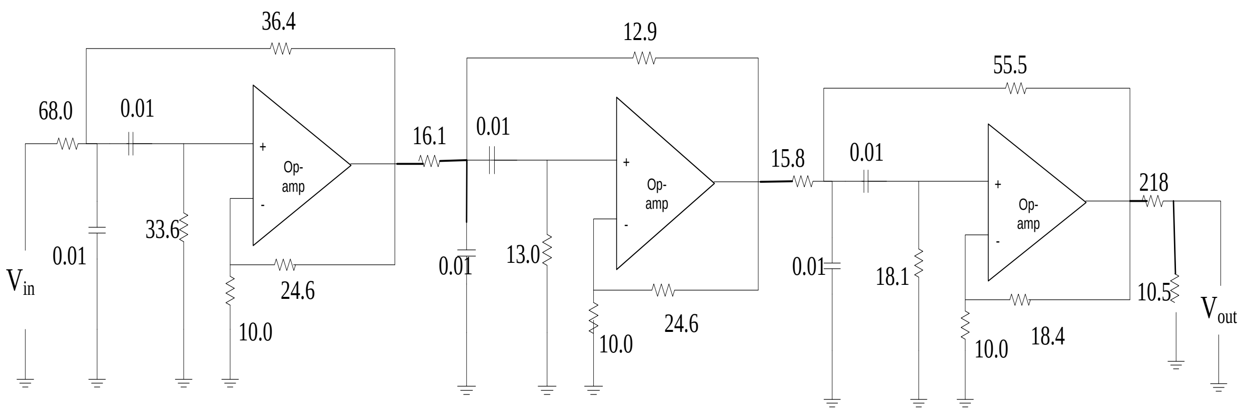


Fig 5: Bandpass filter stage for 6th order (All resistor values in kΩ and capacitor values in µF)

5. CONCLUSION

At active filter design, the using of classical calculation methods make more difficult to circuit design with different component values. In this study, the using of GA, one of the methods of the heuristic calculation, was proposed at active filter circuits that are preferred at realization of transfer function owing to natural correspondence between electronic circuit and mathematical functions. At work, selection of component value was used for different component values instead of standard series discretely works at literature and the desired amplitude response with that data was reached.

In this study, the improved programme with desired initial conditions was run for circuit design that the user will define its specification and the similar amplitude responses were observed for different conditions.

At work, quadratic bandpass filter layer structure was used but, the programme can be generalized for other filter types such as lowpass, highpass and bandstop using with different circuit models.

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