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# RC Band Pass Filters Analysis for Under damped Operating Conditions

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***Abstract- Filters of some sort are essential to the operation of most electronic circuits. It is therefore in the interest of anyone involved in electronic circuit design to have the ability to develop filter circuits capable of meeting a given set of specifications. delay time steady state error, operating frequency, and wavelength, damping frequency, and wavelength the major interesting design parameters for different categories of signal filtering under operation considerations.***

***Keywords— RC filter, Time response, steady state error, Band pass filter and Peak Time.***

## I. INTRODUCTION

Examples of new sources include more efficient mid ultra violet (UV) lasers, and more conventional broadband sources such as high pressure mercury and xenon arc lamps with improved efficiency and longer lifetimes [1, 2]. A major impediment that continues to make the mid-UV an optically challenging spectral region is the lack of durable optical filters with adequate performance. However, optical filters constructed from thin-film coating materials that have relatively low absorption and spectral dispersion yet high reliability at these short wavelengths would have significant advantages over components such as the diffraction gratings used in monochromators and spectrophotometers. In general, grating-based systems are not as selective and do not achieve as much throughput as filter based systems, and only filters allow direct imaging [3]. Until recently, optical filters for the mid-UV have exhibited poor performance in terms of transmission, spectral selectivity and durability. Optical filters made with soft-coated thin-film materials and/or multiple laminated absorbing and transparent glass substrates cannot withstand the intense energies of illumination at mid-UV wavelengths [4-8].

Hybrid metal dielectric filters also have poor optical damage thresholds, and inadequately low transmission and edge steepness. Optical filters with good performance in the mid-UV are crucial for enabling important new instruments based on applications including biochemical absorption, fluorescence and spectroscopy, as well as for realizing the full potential of industrial applications in areas including semiconductor and electronics manufacturing [9-12].

## II. MODELING ANALYSIS

### II. 1. RC BAND PASS FILTER

Figure 1 shows a band pass filter. It is a combination of a high pass filer and a low pass filter. Since neither low nor high frequency signals can pass through, this is a band pass filter.

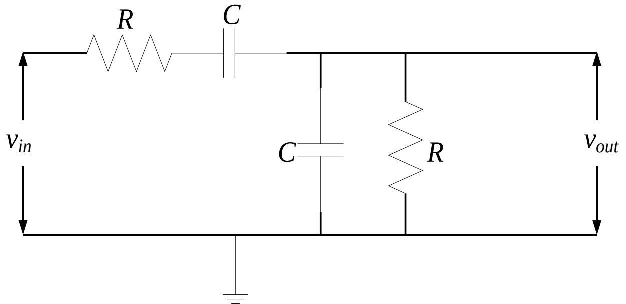

Fig. a. An RC band pass filter.

The RC band pass filter (BPF) transfer function can be given by the following formula [13]:

Thus,
$$A(S)=\frac{\frac{R}{1+SRC}}{\frac{1+SRC}{SC}+\frac{R}{1+SRC}} =\frac{SRC}{S^2R^2C^2+3SRC+1} =\frac{\frac{S}{RC}}{S^2+\frac{3S}{RC}+\frac{1}{R^2C^2}} \quad (1)$$

If the input is unit step function, then the output as a function of time constant (t) can be expressed as [13, 15]:

$$v_{out}(t)=\frac{e^{-\frac{\xi}{RC}t}}{\sqrt{1-\xi^2}}Sin\left(f_d\,t+\phi\right) \quad (2)$$

Where $f_d$ is the damping frequency, φ is the phase shift, ξ is the damping ratio, and time constant, t can be expressed as:

$$t=RC \quad (3)$$

Based on the second order filter circuit, the operating frequency, $f_0$, and damping frequency, $f_d$ can be given by:

$$f_0=\frac{3}{2\xi R\,C} \quad (4)$$

Where the sets of the parameter of $f_d$, $T_r$, $T_s$, $T_d$, $T_p$ are given by the following mathematical relations [4-11]

$$f_d = f_0\sqrt{1-\xi^2} \quad (5)$$

$$T_r=\frac{1}{f_d}\,Tan^{-1}\left(\frac{1-\xi^2}{\xi}\right) \quad (6)$$

$$T_s=\frac{4}{\xi\ f_0} \quad (7)$$

$$T_d=\frac{1+0.7\ \xi}{f_0} \quad (8)$$

$$T_p=\frac{\pi}{f_0\,\sqrt{1-\xi^2}}=\frac{\pi}{f_d} \quad (9)$$

The percentage steady state error of the RC band pass filter circuit can be described as the following formula [16, 17]:

$$E_{ss}(\%) = \frac{1}{1+RC} x100\% \qquad (10)$$

Where resistance (R) and capacitance (C) in this relation in KΩ and nF respectively.

## III. PERFORMANCE ANALYSIS

Electrical RLC low and RC Band pass filters have been deeply investigated under damped conditions to enhance it performance operation characteristics such as steady state error, rose time, peak time, settling time and delay time over wide range of the affecting operating parameters as shown in Table 1.

Table 1. Operating parameters for Electrical Filters [3, 5, 11, 13].

| **Operating parameter** | **Symbol** | **Value** |
|---|---|---|
| Resistance | R | 10 KΩ-100 KΩ |
| Capacitance | C | 10 nF-100 nF |
| Damping ratio | ξ | 0.2-0.9 |

Based on the modeling equations analysis over wide range of the operating parameters, and the series of the Figs. (1-20), the following features are assured:

i) Figs. (1-3) have assured that resonance frequency (f0) is inversely proportional to capacitance and resistance, when capacitance and resistance increase then operating frequency decrease, when the damping ratio increase then operating frequency (f0) decrease at the assumed set of operating parameter.

ii) Figs. (4-6) have assured that damping frequency (fd) is inversely proportional to capacitance and resistance, when capacitance and resistance increase then damping frequency decrease, when the damping ratio increase then damping frequency decrease at the assumed set of operating parameter.

iii) Figs. (7-9) have assured that Rise time (Tr) is directly proportional to capacitance and resistance, at the assumed set of operating parameter.

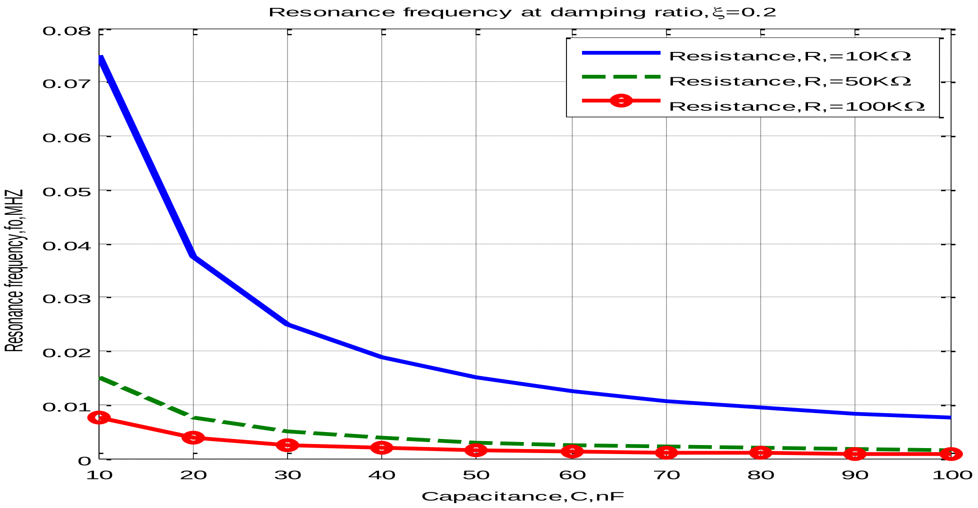

Fig .1. variation of resonance frequancy $f_0$ against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

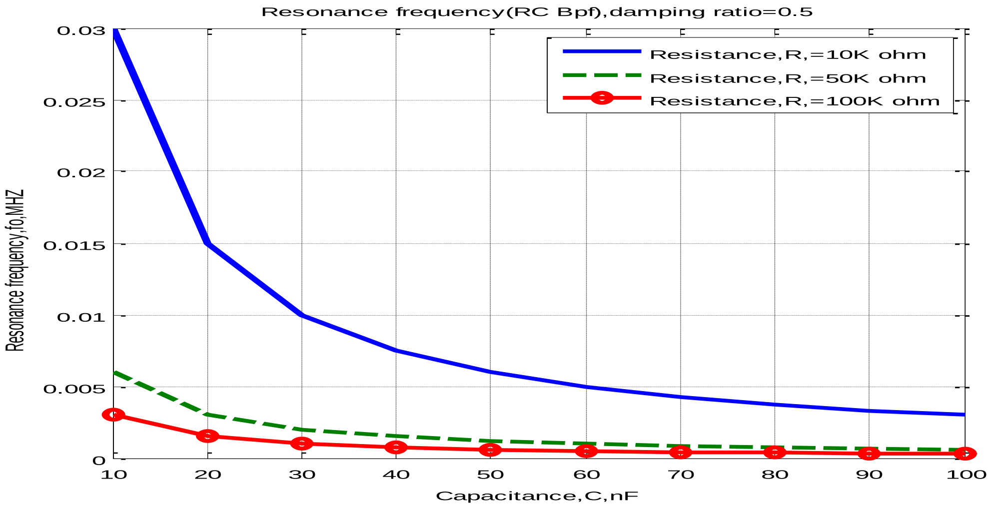

Fig .2. variation of resonant frequancy f0 against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

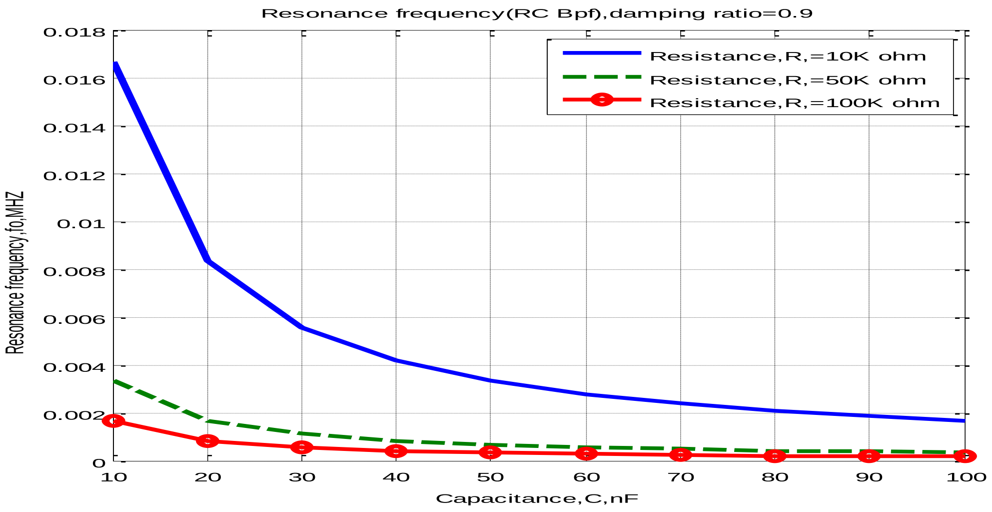

Fig .3. variation of resonant frequancy f0 against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

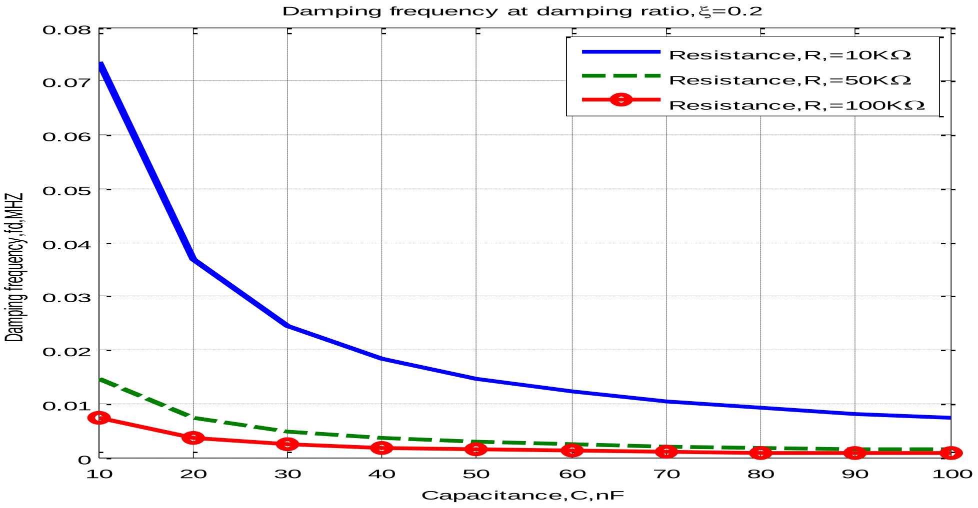

Fig .4. variation of damping frequancy fd against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

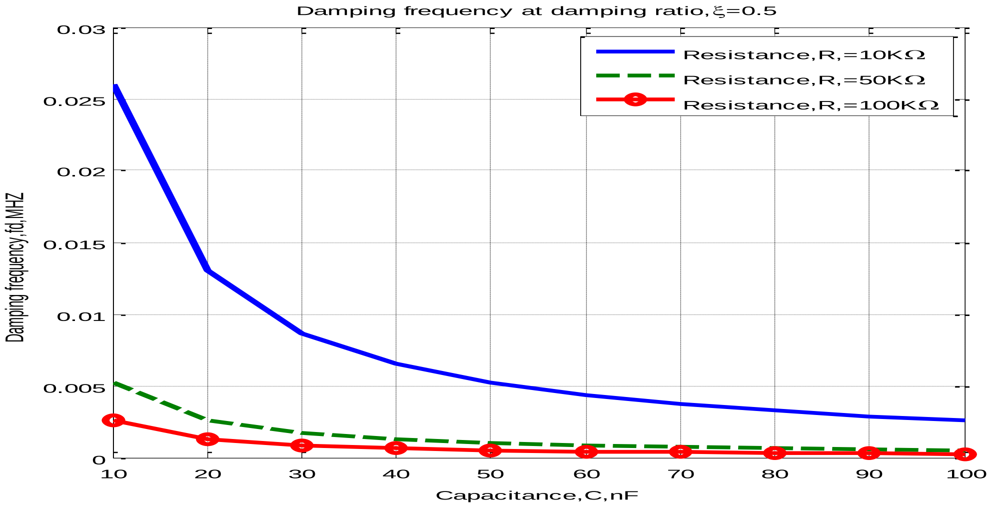

Fig .5. variation of damping frequancy fd against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

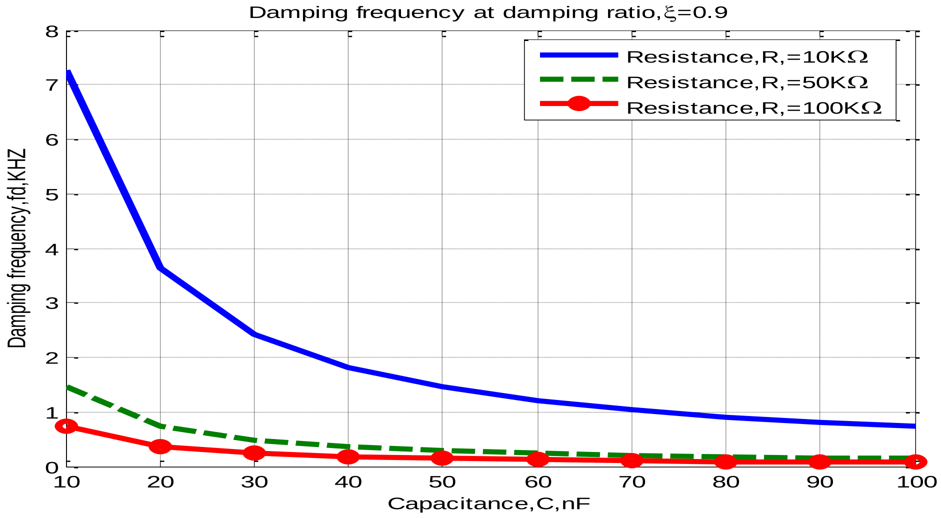

Fig .6. variation of damping frequancy fd against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

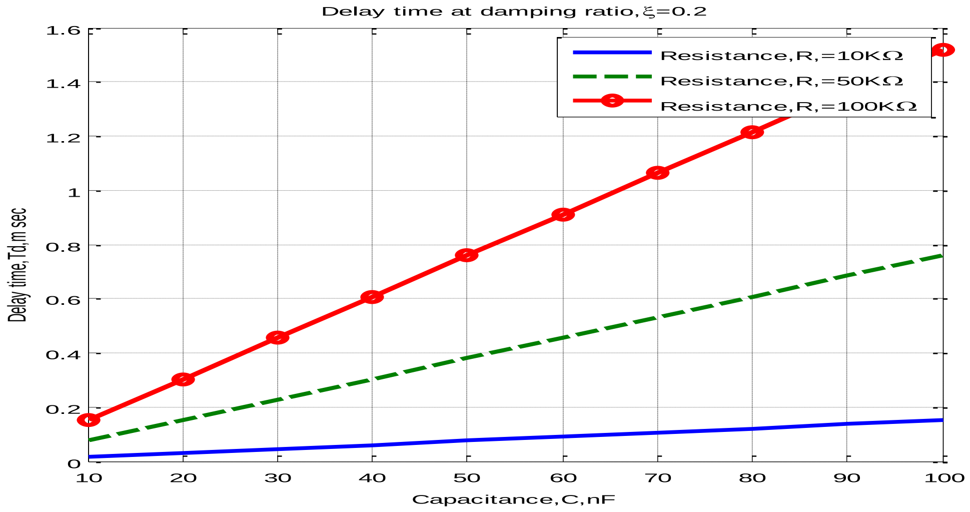

Fig .7. variation of delay time Td against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

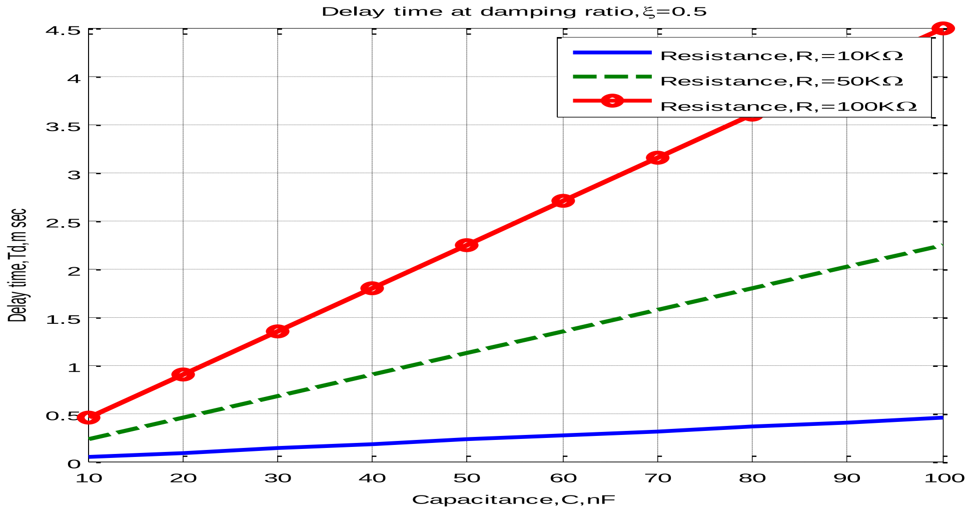

Fig .8. variation of delay time Td against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

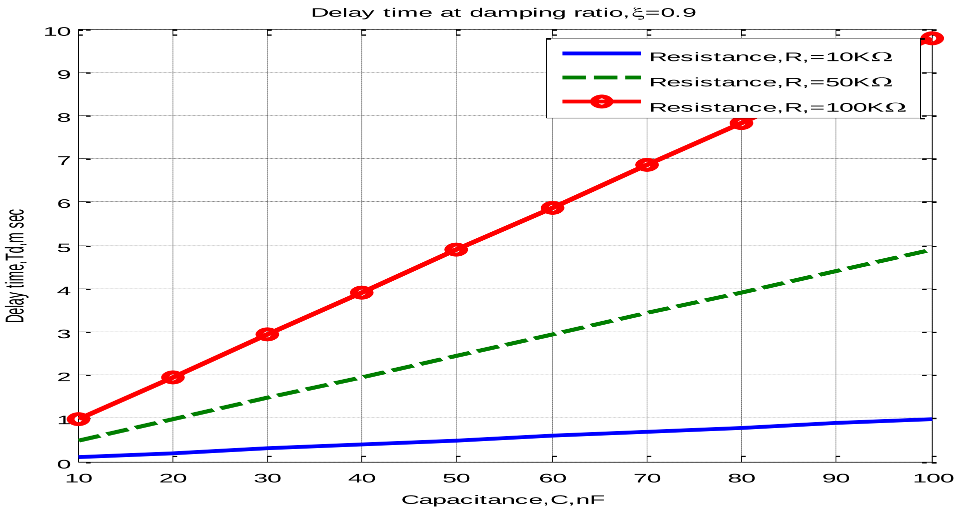

Fig .9. variation of delay time Td against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

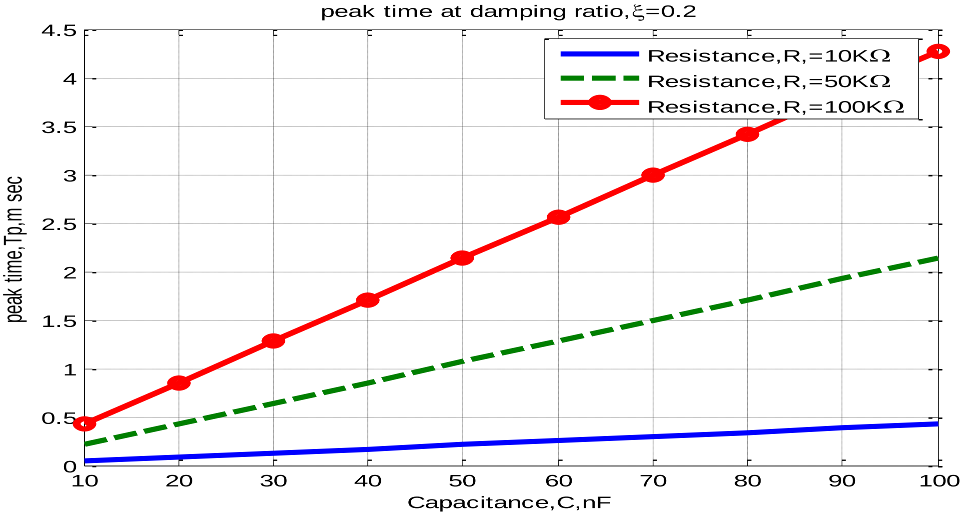

Fig .10. variation of peak time Tp against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

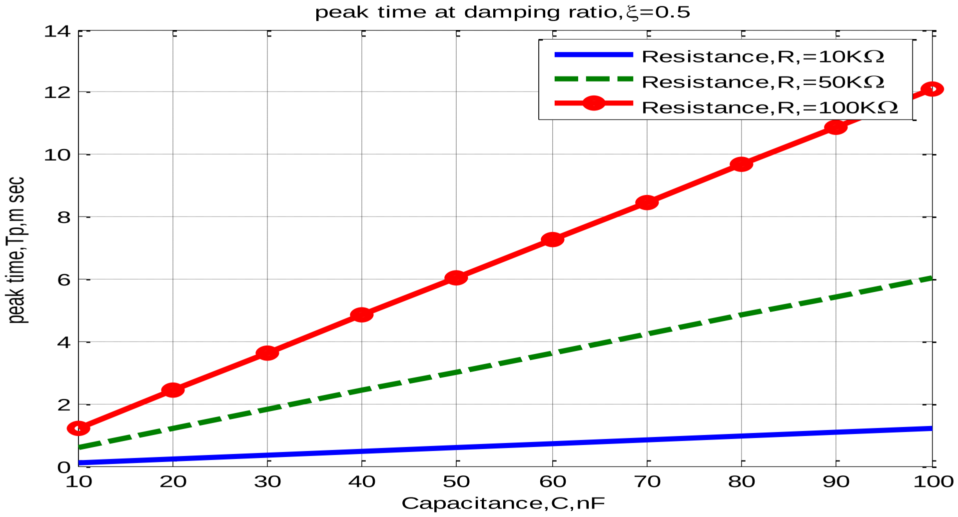

Fig .11. variation of peak time Tp against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

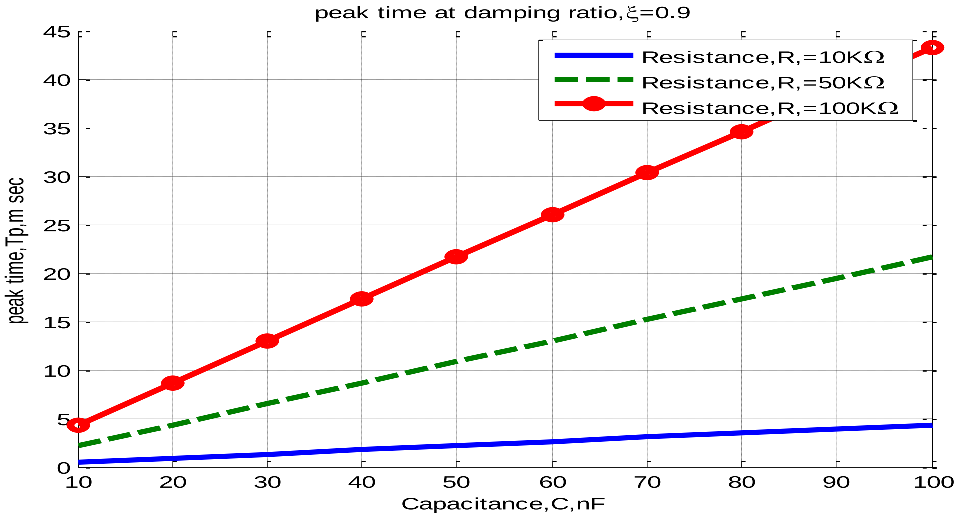

Fig .12. variation of peak time Tp against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

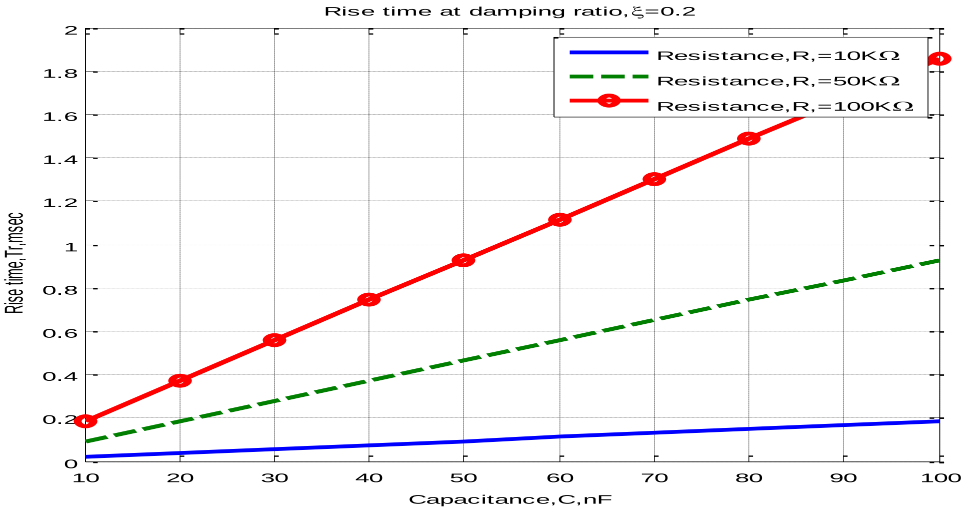

Fig .13. variation of Rise time Tr against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

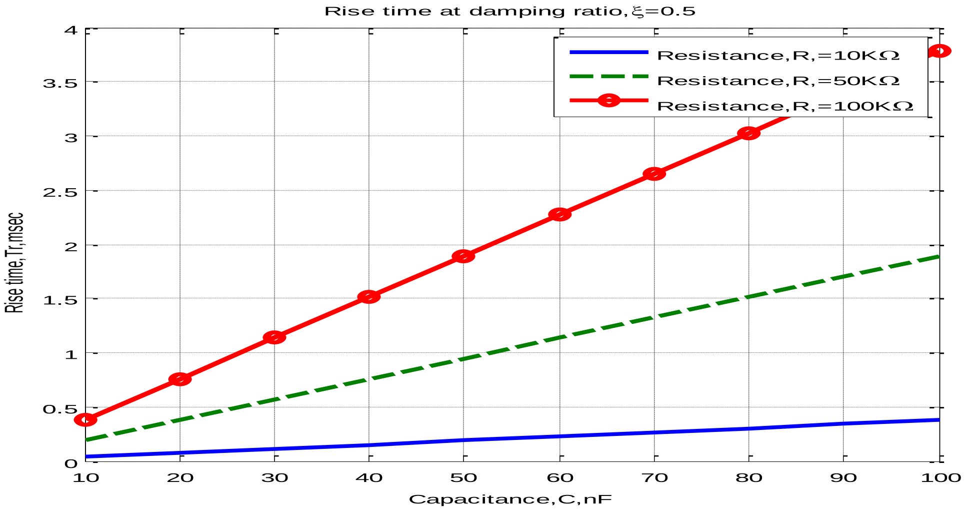

Fig .14. variation of Rise time Tr against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

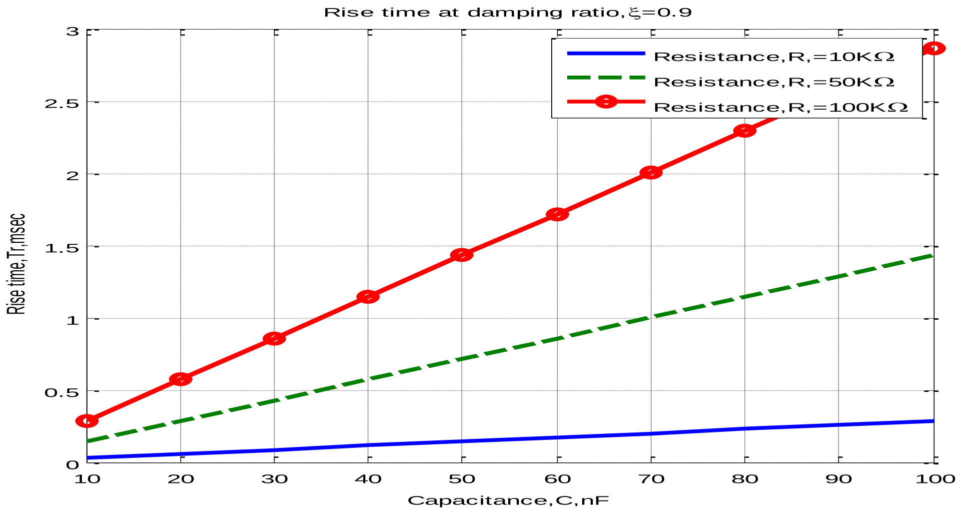

Fig .15. variation of Rise time Tr against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

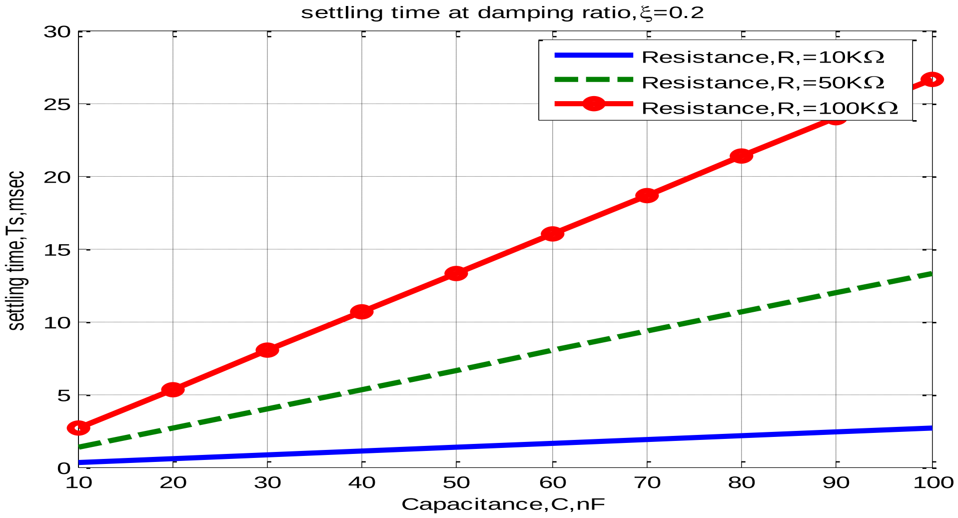

Fig .16. variation of settling time Ts against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

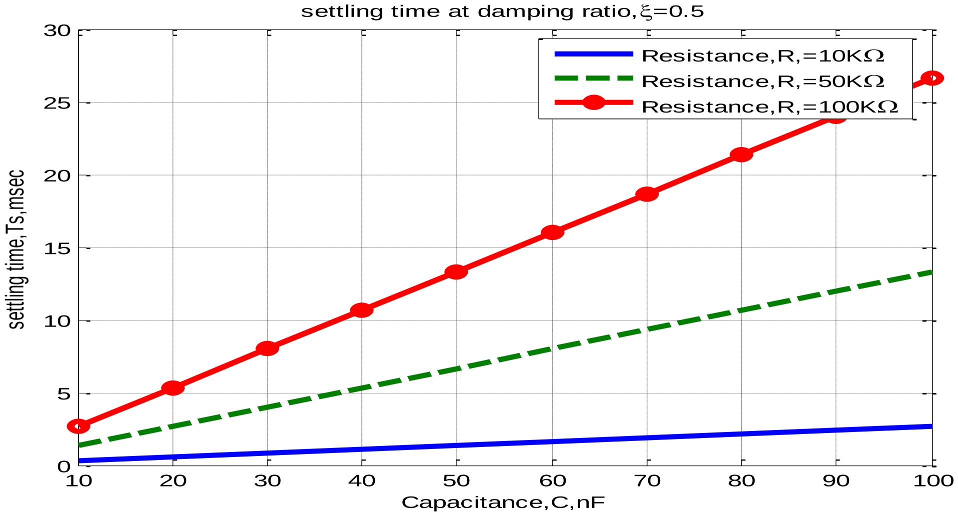

Fig .17. variation of settling time Ts against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

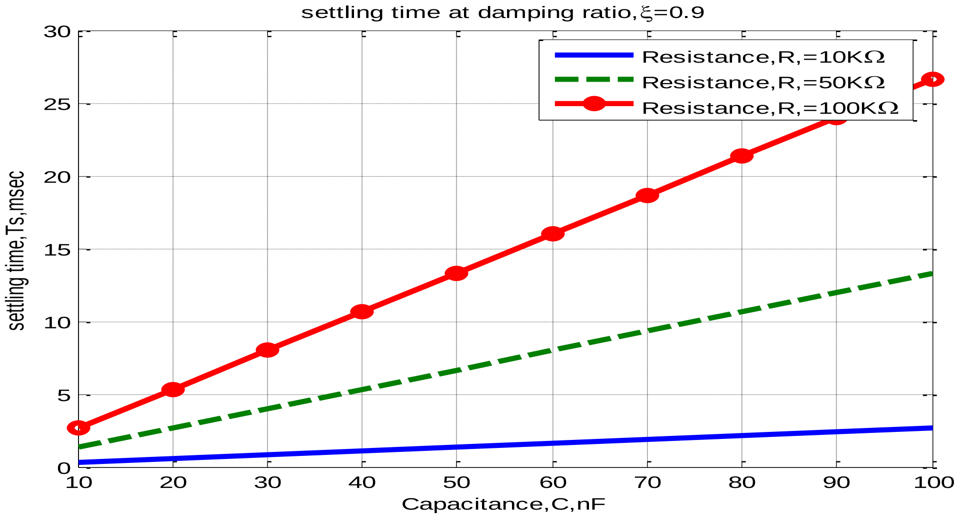

Fig .18. variation of settling time Ts against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

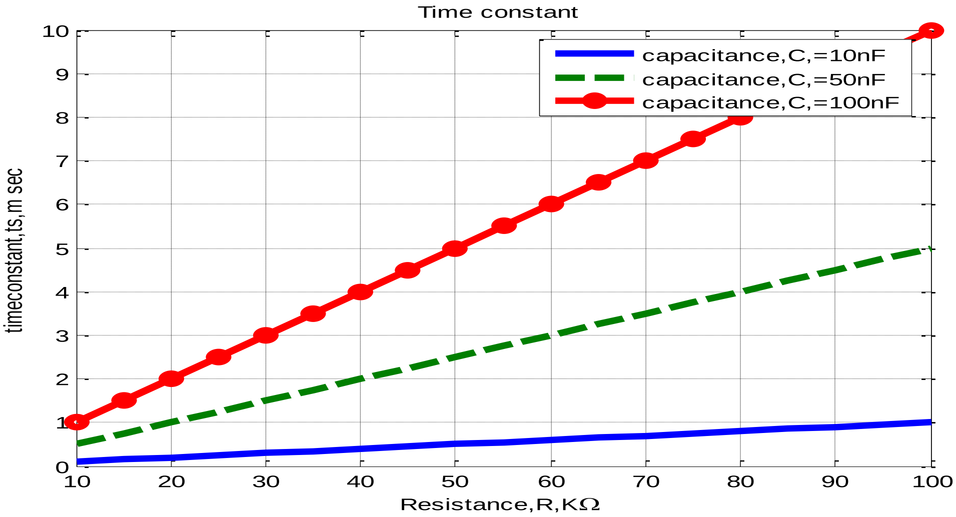

Fig .19. variation of time constant Tc against variation of capacitance with inductance assumed set of the operating parameters

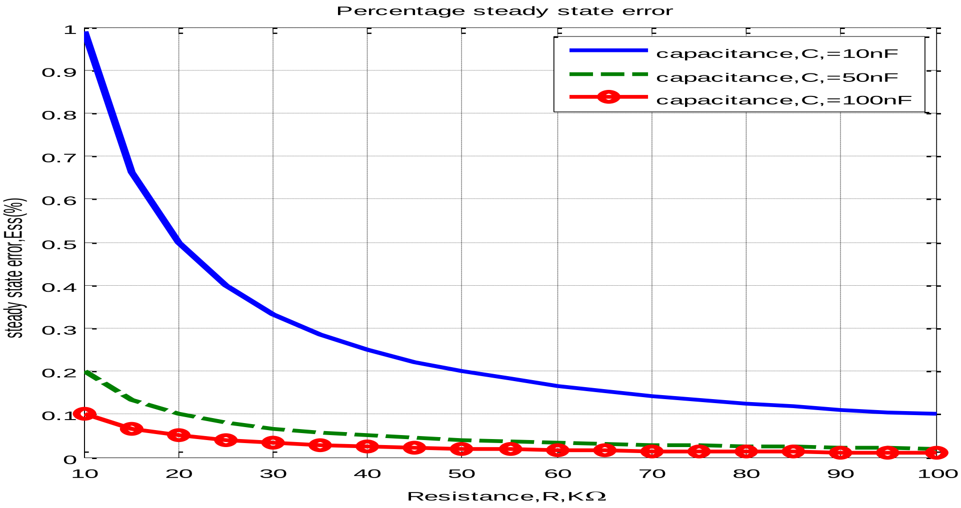

Fig .20. variation of steady state error [Ess] against variation of inductance with capacitance assumed set of the operating parameters.

iv) Figs. (10-12) have assured that settling time (Ts) is directly proportional to capacitance and resistance, at the assumed set of operating parameter.

v) Figs. (13-15) have assured that Delay time (Td) is directly proportional to capacitance and resistance, at the assumed set of operating parameter.

vi) Figs. (16-18) have assured that peak time (Tp) is directly proportional to capacitance and resistance, at the assumed set of operating parameter.

vii) Figs. (19) have assured that time constant is directly proportional to capacitance and resistance, when capacitance and resistance increase then time constant increase, at the assumed set of operating parameter.

viii) Fig (20) has assured that the steady state error is inversely proportional to capacitance and inductance, at the assumed set of operating parameter.

## IV. CONCLUSIONS

The filter model has been deeply investigated over wide range of the affecting parameters. It is theoretically found that the capacitance and resistance increase, this results in decreasing of both resonance frequency ($f_0$) and damping frequency ($f_d$). As well as it is theoretically found that when the capacitance and resistance increase this leads to the increasing in rise time ($T_r$), settling time($T_s$), delay time ($T_d$) and peak time ($T_p$). Here is the transient time response operation performance RC band pass filter over under damped systems conditions as listed in Table 2.

Table 2: Transient Time response of RC filters over under damped conditions.

| Transient time response design parameters | RC band pass filter | | |
|---|---|---|---|
| | ξ=0.2 | ξ=0.5 | ξ=0.9 |
| Operating frequency, $f_0$, MHz | 0.075 | 0.03 | 0.017 |
| Damping frequency, $f_d$, MHz | 0.073 | 0.026 | 0.0072 |
| Rise time, $T_r$, msec | 1.85 | 3.78 | 2.86 |
| Settling time, $T_s$, msec | 26.6 | 26.67 | 26.6 |
| Delay time, $T_d$, msec | 1.52 | 4.5 | 9.7 |
| Peak time, $T_p$, msec | 4.27 | 12 | 43.2 |

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## Author's Profile

**Dr. Ahmed Nabih Zaki Rashed** was born in Menouf city, Menoufia State, Egypt country in 23 July, 1976. Received the B.Sc., M.Sc., and Ph.D. scientific degrees in the Electronics and Electrical Communications Engineering Department from Faculty of Electronic Engineering, Menoufia University in 1999, 2005, and 2010 respectively. Currently, his job carrier is a scientific lecturer in Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia university, Menouf. Postal Menouf city code: 32951, EGYPT. His scientific master science thesis has focused on polymer fibers in optical access communication systems. Moreover his scientific Ph. D. thesis has focused on recent applications in linear or nonlinear passive or active in optical networks. His interesting research mainly focuses on transmission capacity, a data rate product and long transmission distances of passive and active optical communication networks, wireless communication, radio over fiber communication systems, and optical network security and management. He has published many high scientific research papers in high quality and technical international journals in the field of advanced communication systems, optoelectronic devices, and passive optical access communication networks. His areas of interest and experience in optical communication systems, advanced optical communication networks, wireless optical access networks, analog communication systems, optical filters and Sensors. As well as he is editorial board member in high academic scientific International research Journals. Moreover he is a reviewer member in high impact scientific research international journals in the field of electronics, electrical communication systems, optoelectronics, information technology and advanced optical communication systems and networks.