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RLC Low Pass Filters Transmission Transient Performance Characteristics Analysis

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Abstract*— *Filter is considered as a part of an optical system that has the purpose of modifying the intensity, polarization or, in particular, the spectral distribution of light. For reconfigurable filters a signal is applied to tune the filter' s properties or change between different configurations. 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*— *Time response, steady state error, steady state output, Low 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].

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 [5-7].

II. FILTER MODELING ANALYSIS

II. 1. RLC LOW PASS FILTER

RLC low pass Filters can be designed by using inductors, capacitors and resistors as shown in Fig. 1. RLC low pass filters output is taken from capacitor side.

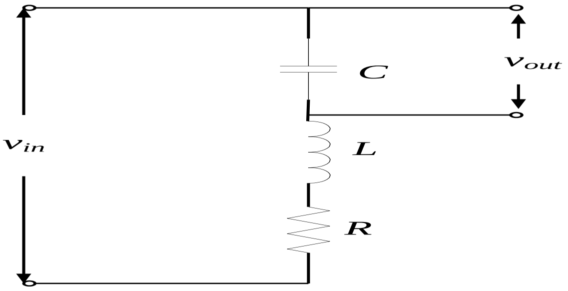

Fig. 1. An RLC low pass filter.

The RLC low pass filter (LPF) transfer function (Gain) can be expressed as the following formula [8]:

$$\frac{v_{out}}{v_{in}}=\frac{\frac{1}{SC}}{SL+\frac{1}{SC}+R}=\frac{1}{S^2LC+1+SRC}=\frac{\frac{1}{LC}}{S^2+S\frac{R}{L}+\frac{1}{LC}} \qquad (1)$$

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

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

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:

$$t=\sqrt{L\,C} \qquad (3)$$

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

$$f_0=\frac{R}{2\xi\sqrt{L\,C}} \qquad (4)$$

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

As well as the phase shift of filter circuit, φ can be expressed as the following formula [9]:

$$\phi=Tan^{-1}(\frac{\sqrt{1-\xi^2}}{\xi}) \qquad (6)$$

The rise time T_r, and settling time T_s, of the filter circuit can be given by [10]:

$$T_r=\frac{1}{f_d}Tan^{-1}\left(\frac{1-\xi^2}{\xi}\right) \qquad (7)$$

$$T_s=\frac{4}{\xi\;f_0} \qquad (8)$$

In the same way, the delay and peak times, T_d, and T_p are described by the following expressions [11]:

$$T_d = \frac{1+0.7\,\xi}{f_0} \qquad (9)$$

$$T_p = \frac{\pi}{f_0\,\sqrt{1-\xi^2}} = \frac{\pi}{f_d} \qquad (10)$$

The percentage steady state error of the RLC low pass filter circuit can be described as the following formula [12]:

$$E_{ss}(\%) = \frac{1}{1+\sqrt{L\,C}}\;x100\% \qquad (11)$$

Where inductance (L) and capacitance (C) in this relation in µH and nF respectively.

III. PERFORMANCE ANALYSIS

RLC low 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
Inductance	L	0.1 µH- 1 µH
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. (1-19), the following features are assured:

i) Figs. (1-4) have assured that the resonance frequency is inversely proportional to capacitance and inductance, when capacitance and inductance increase this leads to the resonance frequency decreases. As well as, when the damping ratio increases this leads to the Resonance frequency (f0) decreases at the assumed set of operating parameter.

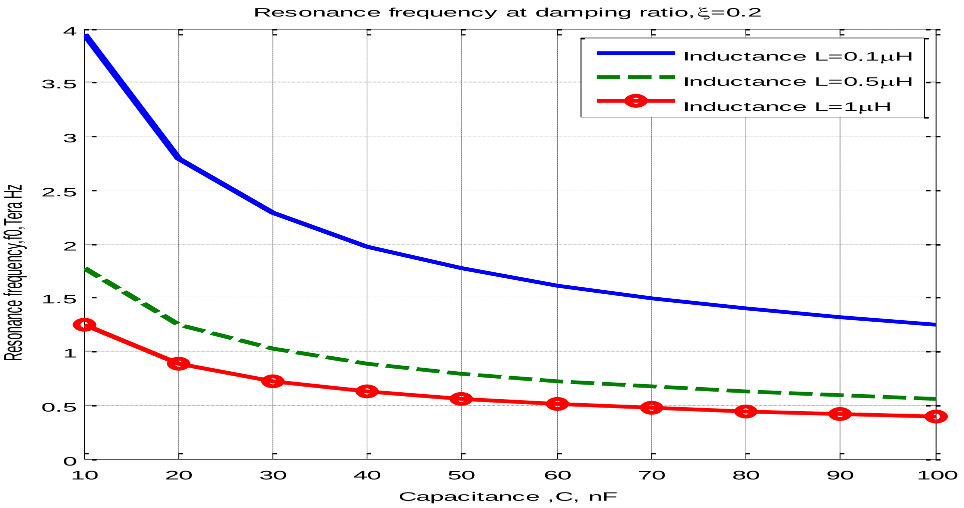

Fig . 1. variation of resonance frequancy f_0 against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

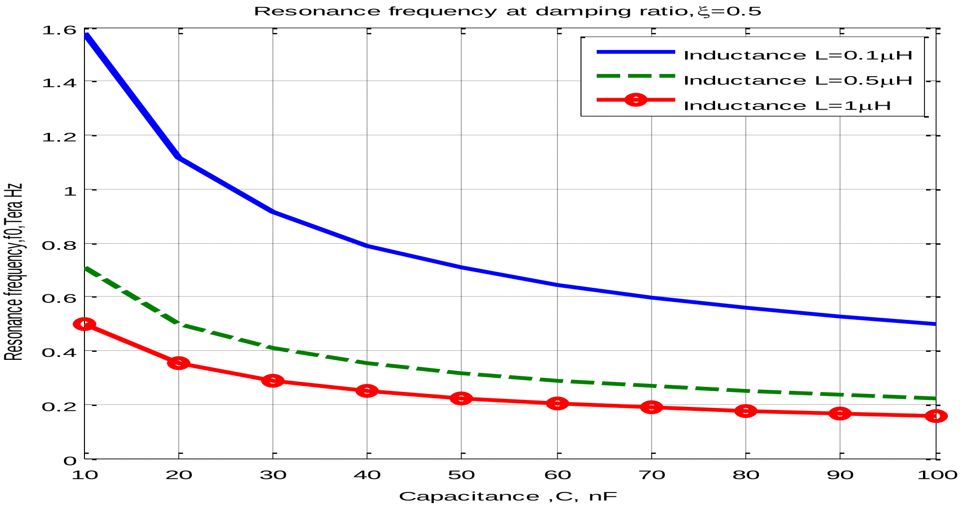

Fig .2. . variation of resonance frequency f_0 against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

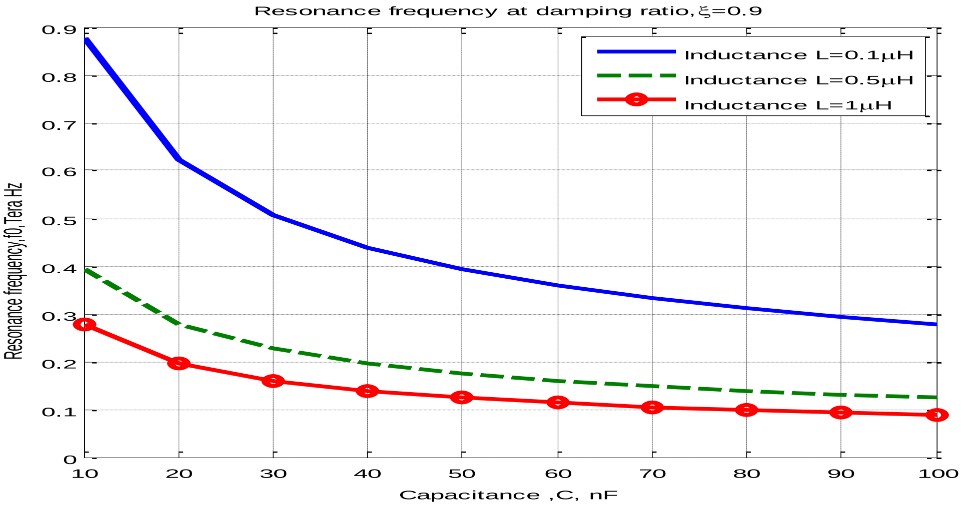

Fig .3. variation of resonance frequency f_0 against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

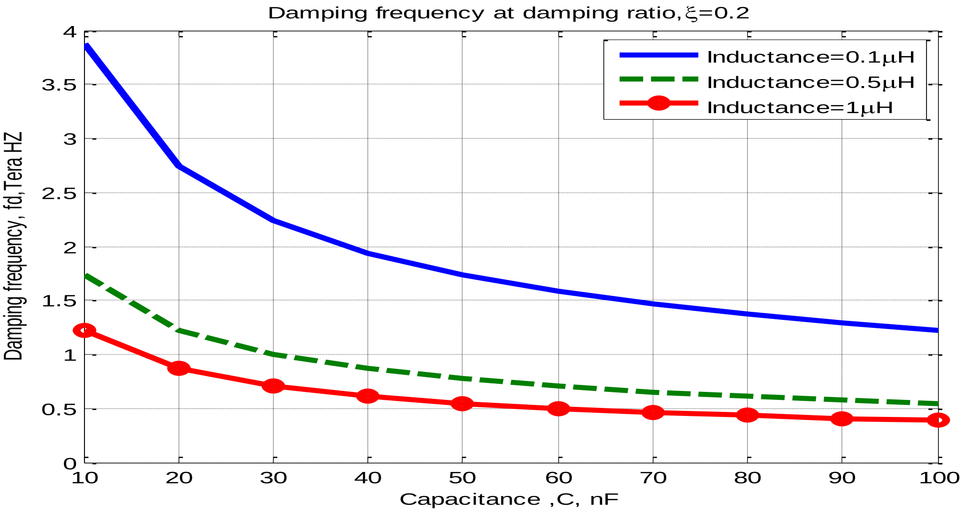

Fig .4. variation of damping frequency f_d against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

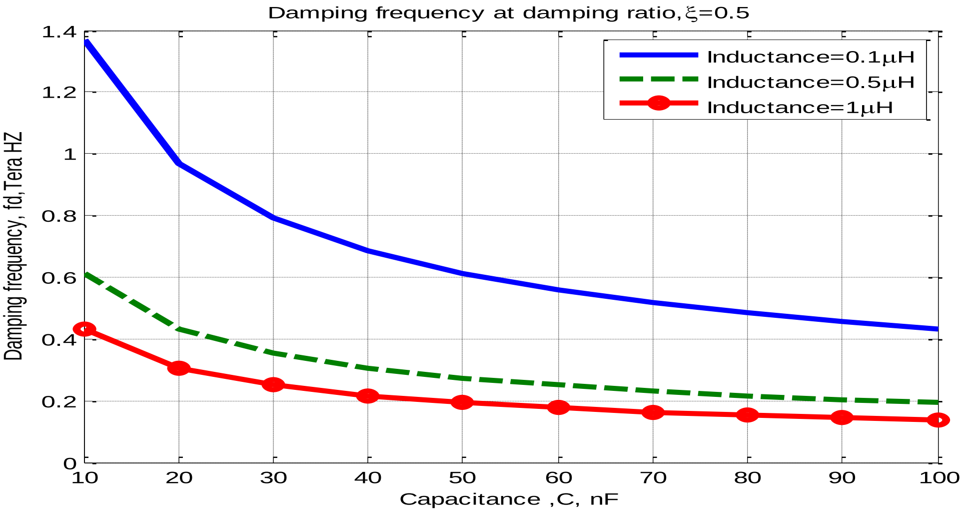

Fig .5. variation of damping frequency f_d against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

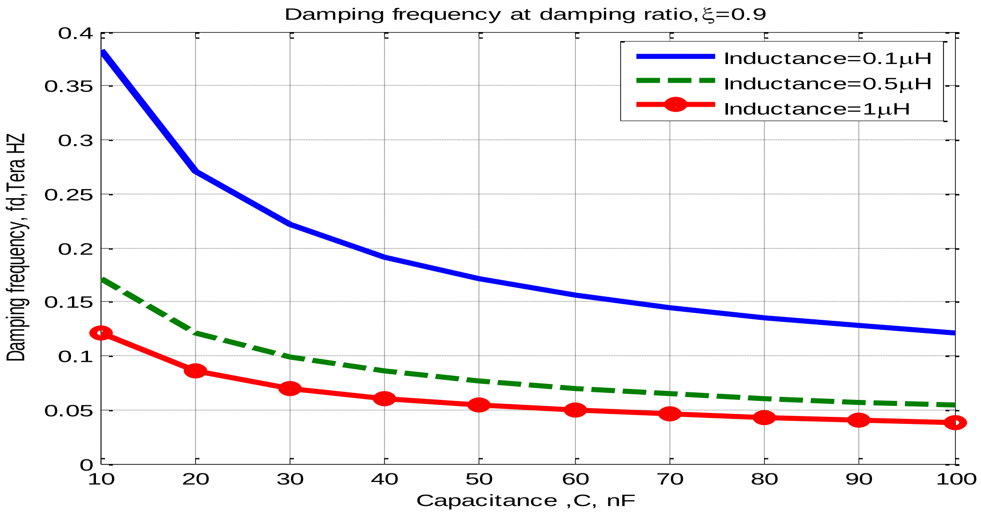

Fig .6. variation of damping frequency f_d against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

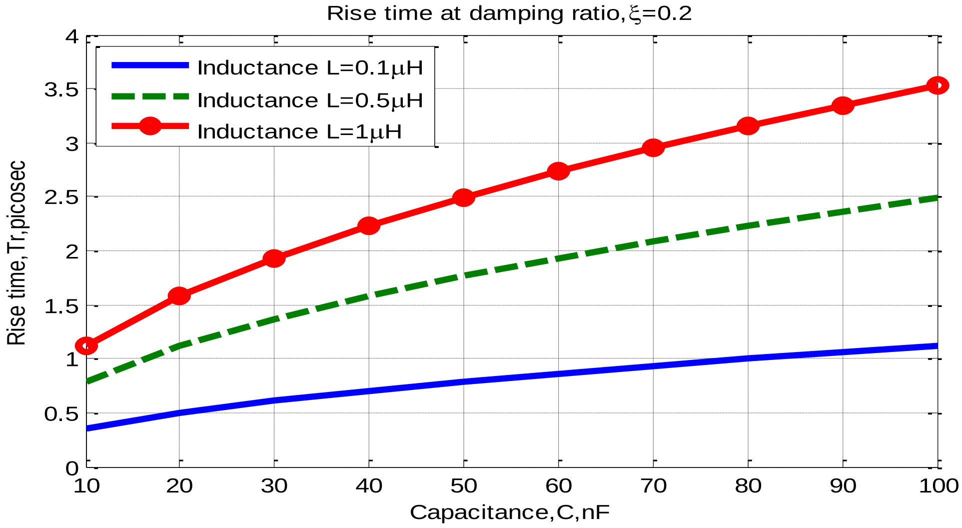

Fig .7. variation of Rise time T_r against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

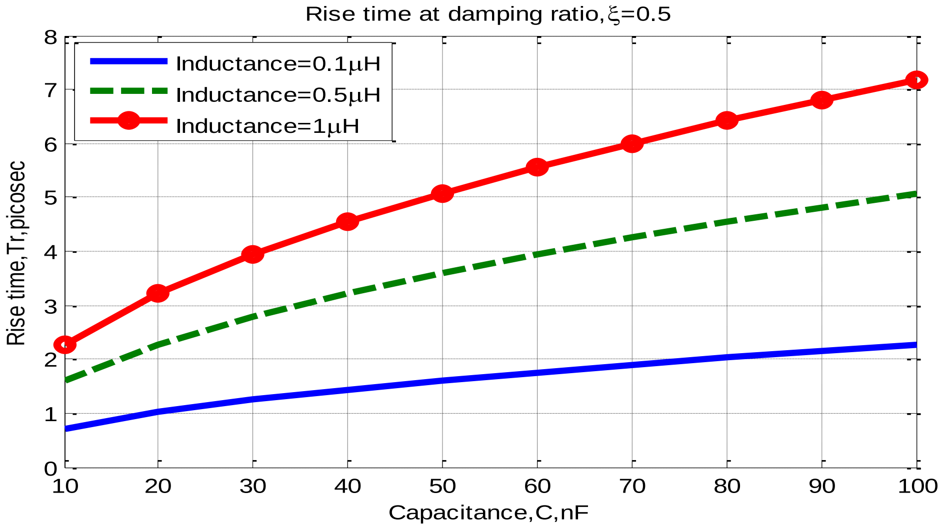

Fig .8. variation of Rise time T_r against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

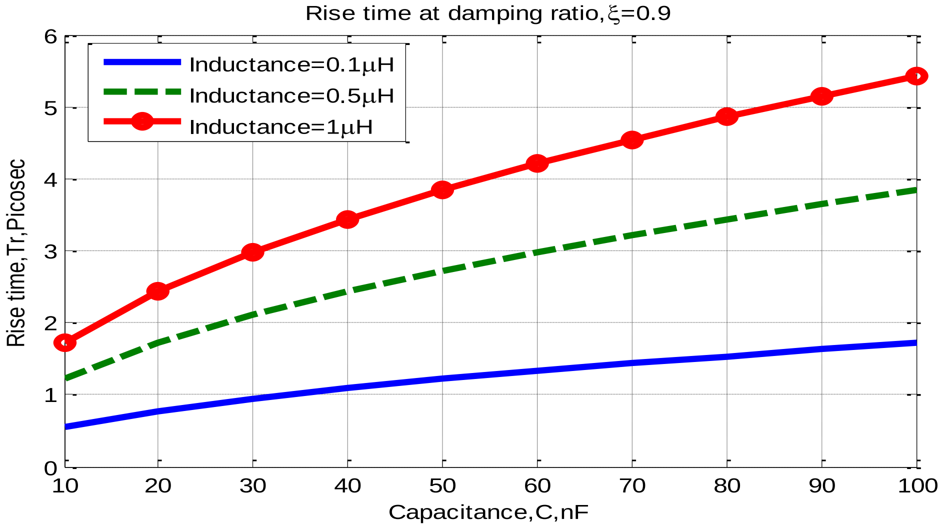

Fig .9. variation of Rise time T_r against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

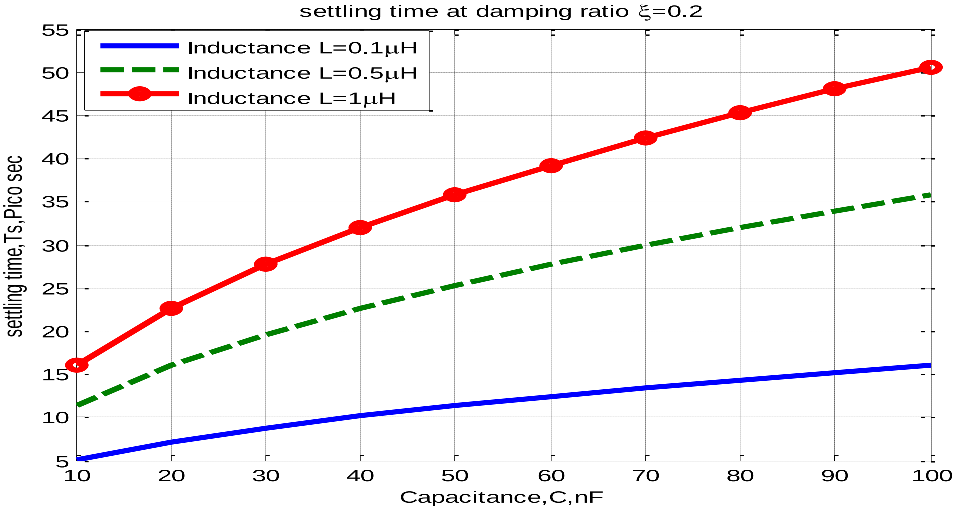

Fig .10. Variation of settling time T_s against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

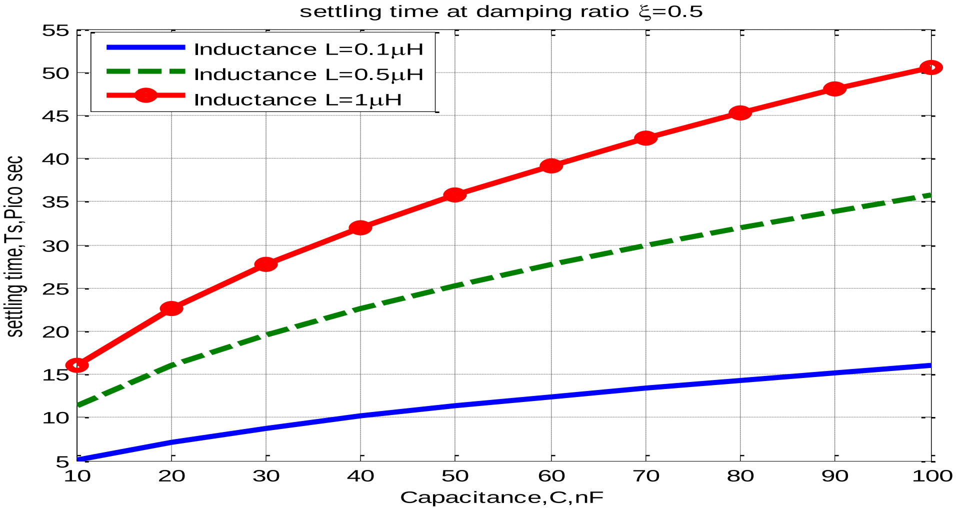

Fig .11. variation of settling time T_s against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

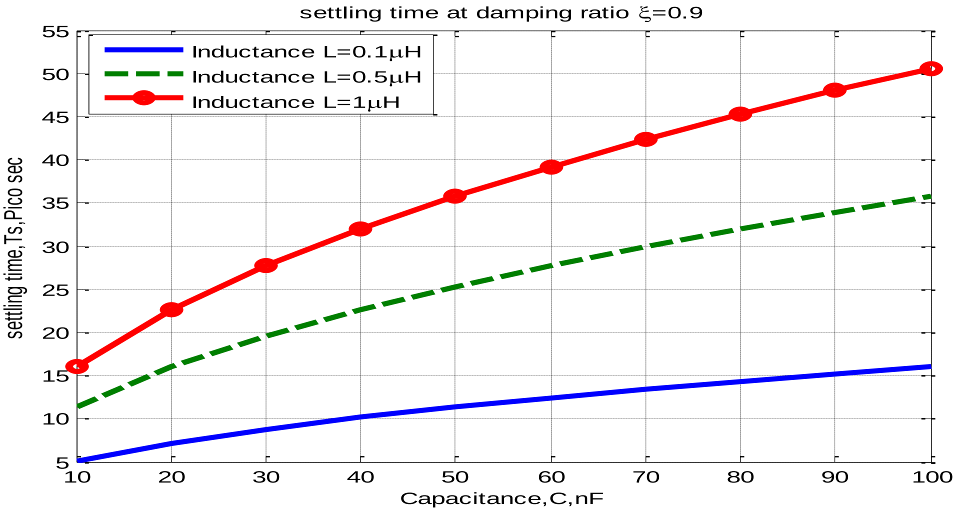

Fig .12. variation of settling time T_s against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

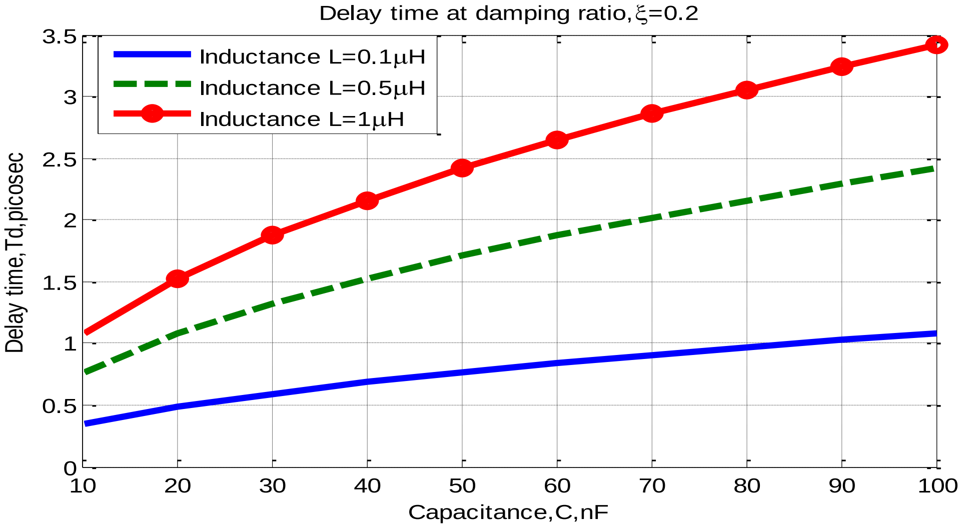

Fig .13. variation of delay time T_d against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

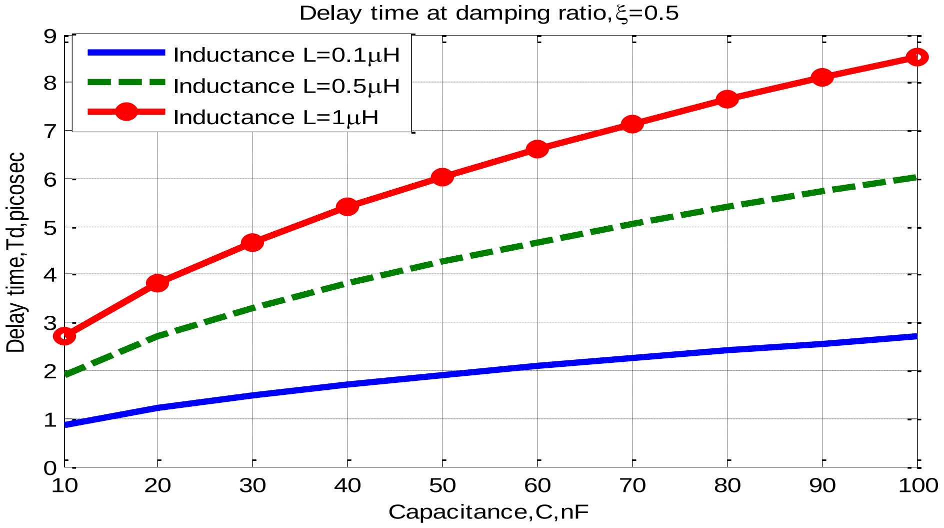

Fig .14. variation of delay time T_d against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

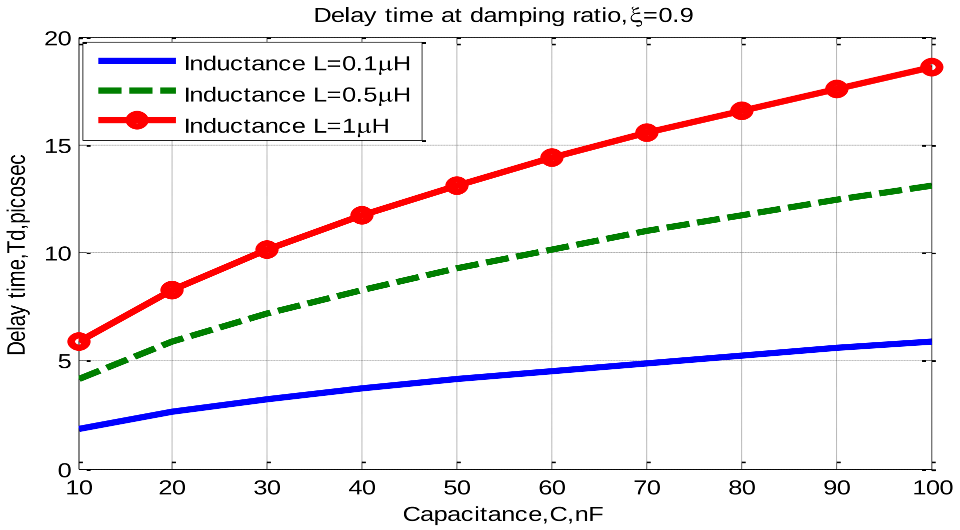

Fig .15. variation of delay time T_d against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

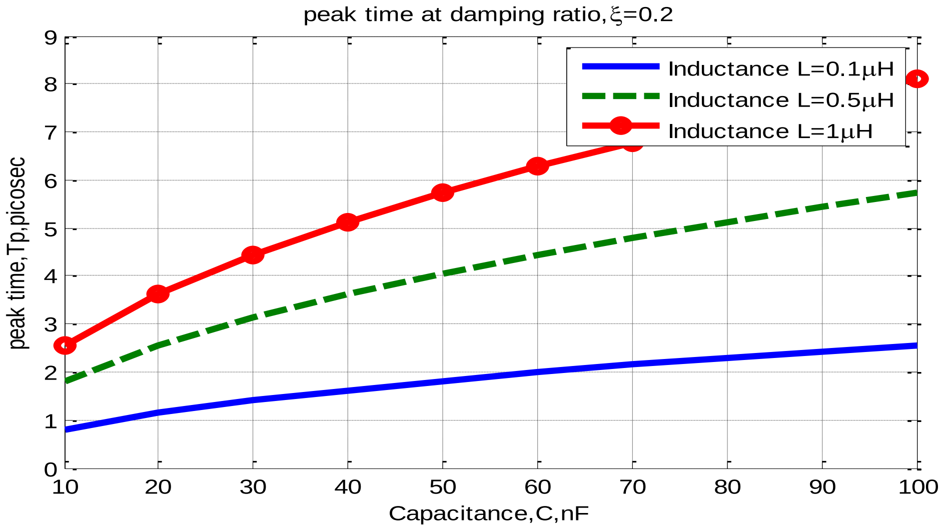

Fig .16. variation of peak time T_p against variation of capacitance with inductance at ξ =0.2 assumed set of the operating parameters

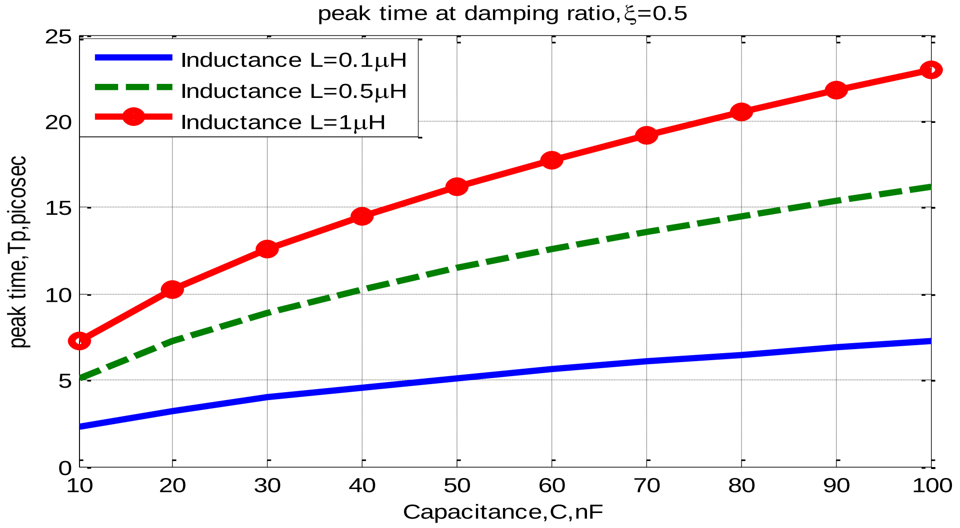

Fig .17. variation of peak time Tp against variation of capacitance with inductance at ξ =0.5 assumed set of the operating parameters

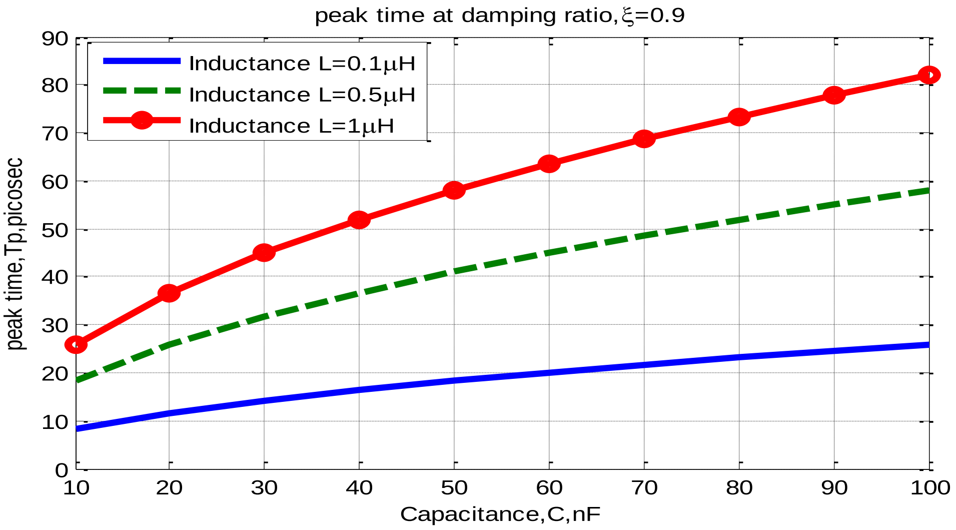

Fig .18. variation of peak time Tp against variation of capacitance with inductance at ξ =0.9 assumed set of the operating parameters

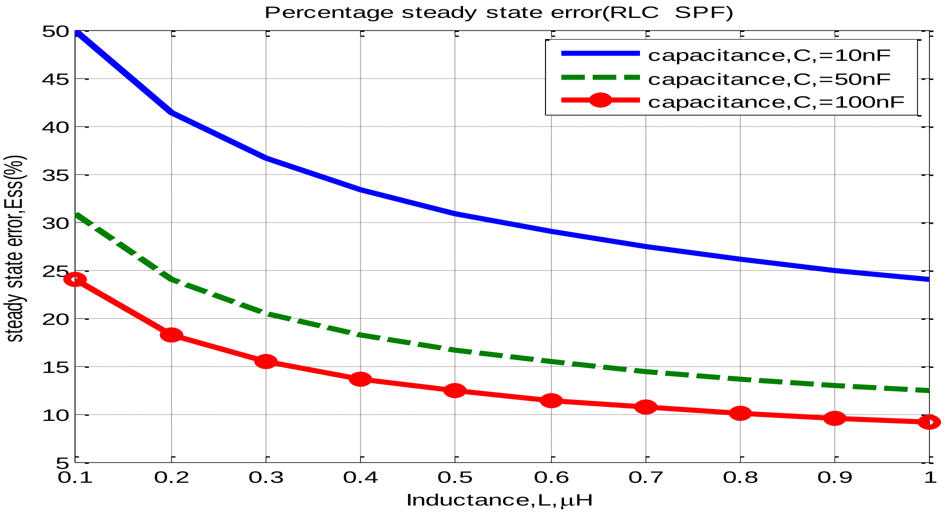

Fig .19. variation of steady state error [Ess] against variation of inductance with capacitance at the assumed set of the operating parameters

ii) Figs. (5-8) have assured that Rise time (Tr) is directly proportional to capacitance and inductance. As well as when damping ratio increases this leads to the Rise time increases, at the assumed set of operating parameter.

iii) Figs. (9-11) have assured that settling time (Ts) is directly proportional to capacitance and inductance. As well as when damping ratio increases this leads to the setting time increases at the assumed set of operating parameter.

iv) Figs. (12-15) have assured that Delay time (Td) is directly proportional to capacitance and inductance. As well as when damping ratio increases this leads to the Delay time increases, at the assumed set of operating parameter.

v) Figs. (16-18) have assured that peak time (Tp) is directly proportional to capacitance and inductance. As well as when damping ratio increases this leads to the Peak time increases, at the assumed set of operating parameter.

vi) Fig. (19) has assured that the steady state error is inversely proportional to capacitance and inductance circuit components at the assumed set of operating parameter.

IV. CONCLUSIONS

In a summary, when the capacitance and resistance increase, then resonance frequency (f_0) and damping frequency (f_d) decrease. As well as it is theoretically found that when the capacitance and resistance increase then rise time(T_r), settling time(T_s), Delay time(T_d) and peak time(T_p) increase. Transient time response operation performance of RLC low pass filters for under damped systems conditions are shown in Table 2.

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

Transient time response design parameters	RLC low pass filter		
	ξ=0.2	ξ=0.5	ξ=0.9
Operating frequency, f_0, THz	3.95	1.58	0.8
Damping frequency, f_d, THz	3.87	1.37	0.3
Rise time, T_r, psec	0.2	0.7	0.5
Settling time, T_s, psec	5	5.1	5.5
Delay time, T_d, psec	0.2	0.85	2
Peak time, T_p, psec	0.8	2.3	9

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Author's Profile

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