ACTIVE RC REALIZATIONS OF DRIVING POINT FUNCTIONS USING OPERATIONAL AMPLIFIERS

A Thesis
Submitted for the degree
of
DOCTOR OF PHILOSOPHY
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By
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Delhi

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CERTIFICATE

Certified that this work, "Active RC Realizations of Driving Point Functions using Operational Amplifiers" by Mr. V. Nagarajan has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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SYNOPSIS

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With the advent of integrated circuits (IC) there is an increasing demand for duplicating the performance of the conventional passive RLC filters by means of circuits containing no inductors. The need for inductorless networks arises primarily because of the fact that the significant size reduction provided by IC technology to resistors and capacitors is not available for inductors. An attractive solution to this problem is to use active elements and RC networks, i.e., the so-called active RC filters and extensive work on this subject has been reported in the literature over the past decade. Also, with the availability of the high performance differential input operational amplifier (DIOA) as an off-the-shelf item in monolithic IC form, many attempts have been made to use it in active network synthesis for realization of driving point as well as transfer functions. Driving point function synthesis is of importance as most of the transfer function synthesis problems can be reduced to the identification and realization of RC one-ports. Further, the active RC simulation of grounded and ungrounded inductors suitable for integration opens the possibility of applying the well known passive RLC synthesis methods directly to the network functions and then utilizing the simulated inductors to replace the passive inductors. The networks resulting from this approach are known to be less sensitive to component variations than those derived by usual active synthesis procedures.

The present thesis deals mainly with the problem of driving point synthesis using operational amplifiers, with particular emphasis on the simulation of grounded as well as ungrounded inductors. The thesis has been divided into six chapters. In chapter 1, we review the various methods of making inductorless filters. Inductance simulating circuits using either the physical properties of devices or the impedance inverting property of a gyrator, are presented and reviewed with their merits and demerits.

In chapter 2, two active circuits for realization of a grounded inductor, using a single unity gain amplifier and RC networks, are considered. It is shown that the inductance parameters are very sensitive to amplifier gain; this can be remedied by using a high gain differential input operational amplifier. Amplifier imperfection in respect to non-zero output impedance is studied. The sensitivity of the tuned circuits using the active inductances is analyzed and conditions for minimum sensitivity are derived. The sensitivity of active tuned circuits is found to be less than that of an ordinary passive LCR tuned circuit.

In chapter 3, a general active RC configuration employing a unity gain amplifier and 2-port RC networks is considered and the two inductance simulating circuits reported in chapter 2 are derived as special cases. The above two circuits present non-ideal inductors of series kind in that they simulate inductances in series with a resistance. So the value of Q that can be obtained from these circuits is limited. A new circuit for realizing an ideal solid state inductance using a DIOA in the unity gain connection is derived from the proposed general active RC configuration. Sensitivity of the tuned circuit using this high-Q active inductance to component variations is also studied. With a suitable capacitor connected across the input terminals of this new circuit one obtains a tuned oscillator optly suited for microminiature applications.

In chapter 3, we also discuss an active RC network consisting of a unity gain amplifier and a twin-T network which readily realizes a tank circuit, consisting of a parallel connection of two branches with L_1 and R_1 in one and C_2 and $-R_2(\omega)$ in the other. An inductorless bandpass section is constructed using the above configuration with floating power supplies for the series branches.

The circuits presented in the preceding chapters realize the grounded version of an inductor. In order to extend the approach of inductance-replacement to all types of filters, it is clear that a method for direct simulation of a floating inductor is necessary. Chapter 4 presents a scheme for realizing an arbitrary floating immittance function using two operational amplifiers only. The specific case of ungrounded inductor realization is investigated in detail. Experimental results are given for a filter utilising the above simulated inductance. Sensitivity of the simulated inductance to component tolerances is found to be within acceptable limits and the spread of the elements is unity. Hence the scheme is quite suited for IC fabrication. A modification of the above circuit configuration using three operational amplifiers and an UCNIC is also reported in this chapter.

In chapter 5, a new synthesis scheme for obtaining a 3-terminal network from a prescribed set of Z or Y parameters is presented. This scheme makes use of the active RC circuit for floating immittance realization reported in chapter 4. As any 3-terminal network can be reduced to either a π-structure in terms of its Y-parameters or a T structure in terms of its Z-parameters, one can realize the individual branches of T or π from the given specifications and then connect them together to get the required unbalanced two-port. The passive realization of the branch specifications is not possible unless they are positive real functions. Active RC realization presents no problem as the proposed active RC configuration of chapter 4 can realize any arbitrary real rational floating immittance function.

Chapter 6 summarizes the main results of the thesis and also contains a discussion on the scope of further work.

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