MWCNT-Polymer Based Solid-State Fractional Capacitor: Fabrication and Performance Study

Abstract

The main objective of this work is fabrication of solid-state fractional capacitor using MWCNT-polymer nanocomposite with predefined specification. It is able to overcome some of the disadvantages of the fractional capacitors reported in the existing literature: such as tedious fabrication procedure, size, spillage issue, no parameter to tune fractional exponent (α). With the defined fabrication procedure, the fractional capacitors are manufactured and then, the conduction mechanisms in the constant phase zone of the device are identified by correlating the nanocomposite characterization with the electrical properties of the fractional capacitors. Later, a statistical study on those devices are carried out to find the combination of parameters which can provide a varying constant phase angle (CPA).

To make the solid-state fractional capacitors accessible to the research community, guidelines for the fabrication of fractional capacitor with specific parameters have been proposed. For that, batch analysis of the solid-state fractional capacitors fabricated with the potential combination of parameters (obtained from the statistical analysis) are carried out to get the predefined specifications: fractance (F1) and fractional exponent (α).

Different electrical circuits are designed and tested to study the performance of the fractional capacitor as an electronic component. In this thesis, the design and implementation of an astable multivibrator employing the solid-state fractional capacitor is reported. The circuit provides three signals − sine, triangular and square wave if it satisfies the given design rules. The design criteria for the generation of all the three waveforms are elaborated along with the experimental results. In addition, comparison with the integer order astable multivibrator is also provided.

Last work is related to the application of the solid-state fractional capacitor in controller implementation. For this study, a new algorithm for finding out the gains of the $PI^{\lambda}D^{\mu}$ controller is proposed and one of the combination is realized in hardware to regulate the speed of a second order underdamped system. The comparison of speed response of the system with solid-state fractional capacitor based $PI^{\lambda}D^{\mu}$ controller is done with pole-zero interlacing algorithm based $PI^{\lambda}D^{\mu}$ controller (which is an existing controller structure) and classical PID controller.

Keywords: Solid-state fractional capacitor, MWCNT-epoxy nanocomposite, CPA, fractance, statistical analysis, batch analysis, astable multivibrator, $PI^{\lambda}D^{\mu}$ controller, settling time (T_s), rise time (T_r), % overshoot.