Ferroelectric Capacitor Modelling in LTSpice

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Abstract—Ferroelectrics are materials having switchable spontaneous polarization property. By applying alternating electric field, polarization is switched from one state to another which gives rise to the signature property called hysteresis loop. The ferroelectric material sandwiched between the capacitor plates can impart memory to capacitors, which can be used as single bit non-volatile memory. Ferroelectric capacitor is modelled using Schmitt trigger circuit and RC filters connected in series The circuit model is simulated by changing different physical parameters and the hysteresis property of ferroelectric capacitor is analyzed using Sawyer Tower circuit in LTSpice.

I. Introduction

Memories have been the heart of numerous electronic devices that surround us. In addition to this, non-volatile memory elements are introduced in electronic devices to retain the state in case of any power shut down. For past several decades, ferroelectrics appeared to be the material of significant importance among non-volatile memory devices, due to their hysteretic charge-voltage behavior. Ferroelectricity refers to the characteristics of certain materials that has electric polarization in the absence of external electric field. By applying electric fields, polarization can be reversed. Hence there are more than one energetically degenerate states in ferroelectric materials. By applying a suitable strong electric field (E) it is feasible to change polarization between these states [1–2]. This unique property can be used to store and retrieve digital information. Spontaneous polarization of ferro electric materials disappears above a certain temperature called the transition (or Curie) temperature.

Ferroelectric material sandwiched between capacitor plates can impart memory to capacitors, which can be used as single bit non-volatile memory. They maintain memory without a support from battery or any protection package. Ferroelectricity based nonvolatile memory are charge based. Recent advancement in semiconductor-based memories is the usage of ferroelectric capacitors embedded in CMOS based memory circuits for fabricating Ferroelectric Random-Access Memory.

The Sawyer-Tower circuit is used to characterize ferroelectrics and to measure fundamental phenomena like Polarization, Switching and non-switching half loops, Hysteresis, Fatigue, Retention, and Imprints of ferroelectric capacitors. Hysteresis is measured by placing sample capacitors in series with reference capacitors, voltage is applied across the sample ferroelectric capacitor, while the output is measured across a reference capacitor.

II. Experimental Setup

A. Implementation of Ferroelectric Capacitors

Ferroelectric capacitor model is implemented using the Schmitt trigger circuit which represents the dipoles in the ferroelectric films and high pass filters connected in series. Schmitt trigger is a comparator circuit that makes use of positive feedback to accomplish hysteresis. When Schmitt trigger switches at different voltages depending upon whether it is moving from high to low or low to high, hysteresis loop will be formed. The hysteresis behavior of Schmitt trigger is ideal for representing the ferroelectric capacitor behavior. The Schmitt trigger is followed by second ordered High Pass filter. The RC high pass filter passes the signal above the cutoff frequencies and blocks all other signals.

The measurement of the Hysteresis loop in Ferroelectric capacitor is done using Sawyer-Tower circuit where ferroelectric capacitor is placed in series with the sense capacitor.

The circuit element A1 in the above figure represents the non-inverting Schmitt trigger circuit. C1, C2 capacitors, R1, R2 resistors form the second order high pass filter. The capacitor C3 represents the sense capacitor of Sawyer-Tower circuit.

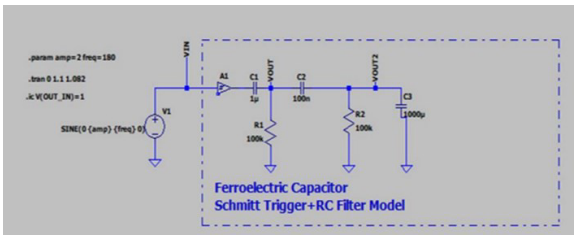

Fig. 1. Sawyer-Tower circuit with Ferroelectric capacitor

III. Experimental Results

Ferroelectric capacitor behavior is studied by varying different parameters in the circuit. The following section explains the behavior of the Ferroelectric capacitor, i.e. the hysteresis loops observed under various conditions..

A. Hysteresis behavior of ferroelectric capacitor under different values of the Sense capacitor

The impact of sense capacitor on the hysteresis loop is studied by varying the value of sense capacitor from 1mF to 1pF. Input sine wave with frequency 180Hz and amplitude 2V is used. The Tau (output RC constant) value of Schmitt trigger

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