A Virtual Instrumentation Environment for Characterizing Dielectric Absorption in Integrated Capacitors

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Outline

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What is Dielectric Absorption?

- A capacitor that has been discharged regains part of its initial voltage
- Modelled as a resistor/capacitor network in parallel with the ideal capacitor
- Is a quality metric of dielectrics in integrated capacitors
- This phenomena affects any circuit with charging and discharging capacitors
Problem Statement

• Accurate DA measurements are difficult to achieve for integrated capacitors
• Voltage in target device becomes comparable to those of parasitic components
Objectives

- Understand the Dielectric Absorption phenomena
- Integrate a test and measurement architecture
- Develop a PCB for accurate measurements
- Develop a Virtual Instrumentation Environment for Dielectric Absorption Measurements
- Perform dielectric absorption measurements on discrete and wafer capacitors
- Perform statistical experiment to evaluate dielectric absorption measurements
- Recommend modifications to the circuit to improve measurements accuracy
Previous Work

- Sencore studied DA to indicate the future behavior of a capacitor\cite{4}.
  - It was found that DA got worse with age in certain capacitors.

- Lacoste performed an experiment to observe DA in large capacitors\cite{1}.
  - He used a DC power supply, a low resistor, an oscilloscope and a large capacitor.

- Kundert studied different methods of modeling dielectric absorption in capacitors\cite{3}.

- Hubbard studied dielectric absorption as a means of characterizing dialectrics\cite{2}.

- Dielectric Absorption coefficient:

\[
\text{Dielectric Absorption} = \frac{\text{remnant voltage}}{\text{Full charge voltage}} \times 100\%
\]
How to perform DAM?

Figure 1: Basic circuit set-up for DAM characterization.
Dielectric Absorption Simulation
Developed Circuit
Measurements Setup Architecture

Internet HUB → TCP/IP → LabVIEW → USB 2.0 → GPIB → GPIB to USB → ArbStudio 1104 → Keithley 2612

LeCroy Waveform → Ch.1 → Driver, DIB & DUT

Switchets Pulses

$V_{cc} = 12V$ & $V_{ss} = -12V$

Input Voltage Pulse
Virtual Instrument Environment

- The Oscilloscope opens signal channels
- The SMU polarizes the integrator
- The SMU sends input current
- The Oscilloscope receives switch and output voltages
- The function generator sends the switch pulses

The SMU

- Sends current
- Receives voltages

The Oscilloscope

- Receives voltages
- Sends current

The function generator

- Sends pulses
- Receives voltages

The integrator

- Receives current
- Sends voltages
Virtual Instrument Environment

- Test input signal setup panel
- Test results panel
Experimental Setup

• Manual dielectric absorption measurement test

• Observed dielectric absorption on a discrete capacitor

• Parameters:
  ◦ Capacitance: 440 µF
  ◦ Resistor: 1 KΩ
  ◦ Frequency: 10 mHz
  ◦ Input current signal: 80µA
  ◦ Charged voltage: 7.4V
  ◦ Switch 1 on time: 50 seconds
  ◦ Switch 2 on time: 10 seconds
Experimental Results
Analysis of Results

• Dielectric Absorption value of 1%

• From the obtained results, the following was identified:
  ◦ Need of smoothing output signal because of noise
  ◦ Amplification of output signal is needed for tests on smaller capacitors
  ◦ Resistor value selector for tests on small or large capacitors
  ◦ Use of a socket for connecting the integrated circuit chip
Conclusions

- Development of a VIE to perform Dielectric Absorption Measurements

- Successfully achieved objectives:
  - Understand Dielectric Absorption phenomena
  - Modelled Dielectric Absorption and simulate its behavior
  - Built a working PCB for Dielectric Absorption measurements
  - Designed a Dielectric Absorption Measurements setup architecture
  - Developed a Virtual Instrument Environment in LabView®
  - Obtained Dielectric Absorption measurement using the built PCB
  - Began to identify ways to improve the circuit
Future Work

• Generate representative samples for different types of capacitors and perform a statistical analysis
• We expect to identify additional opportunities of circuit improvements
• Introduce potential modifications to the circuit and VIE
References


Question & Answers