MOS Capacitor C-V Characteristics

Jahnavi Devangula
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1 Overview of the experiment

1.1 Aim of the experiment

In-lab Experiments:

i. To implement a summer circuit using an Opamp and observe its output.

ii. To implement an amplifier circuit using an Opamp and observe its output.

iii. To measure the C-V characteristics of a MOSCAP.

iv. To calculate the different parameters of a MOSCAP like oxide capacitance, oxide thickness etc. using the experimental and provided data and equations.

1.2 Methods

The steps required to perform this experiment are:

i. For the summer circuit, connect the physical circuit by referring to the given circuit diagram for part 1 and observe its outputs for different inputs to see if it agrees with theoretical outputs.

ii. For the Amplifier circuit, connect the physical circuit by referring to the given circuit diagram for part 2. After that observe its outputs for different inputs and see if it agrees with theoretical outputs. Also, observe the output when low frequency input is given.

iii. For part 3 we have to combine the circuits for parts 1 and 2, so that our circuit looks like the one given in the circuit diagram given in part 3. Now measure the capacitance of the DUT, C_{DUT} as V_{DC} is varied from 0 to 5V.

iv. Lastly, calculate the required parameters using the experimental data and the provided data and equations.

2 Design

In the first and second parts we have to implement a Summer circuit and an Amplifier circuit respectively.

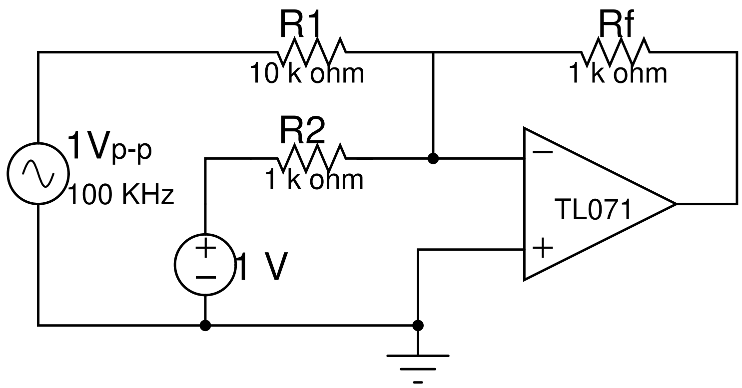
In the third part we have to obtain the C-V characteristics of a MOSCAP and then calculate its required parameters.

2.1 Components Required

- DUT of MOSCAP sample
- TL071 Opamp (x2)
- Resistors - 1kΩ (x2), 10kΩ (x1), 150kΩ (x1)
- Capacitors - 100pF (x2)
- Variable and fixed power supplies, multi-meters
- Breadboard and connecting wires

2.2 Experiment Setup

2.2.1 Part 1: Summer Circuit:



(a) Make the circuit shown above using the Opamp and the other given components.

(b) Observe the output of the Summer circuit for different inputs and check if the outputs agree with theory.

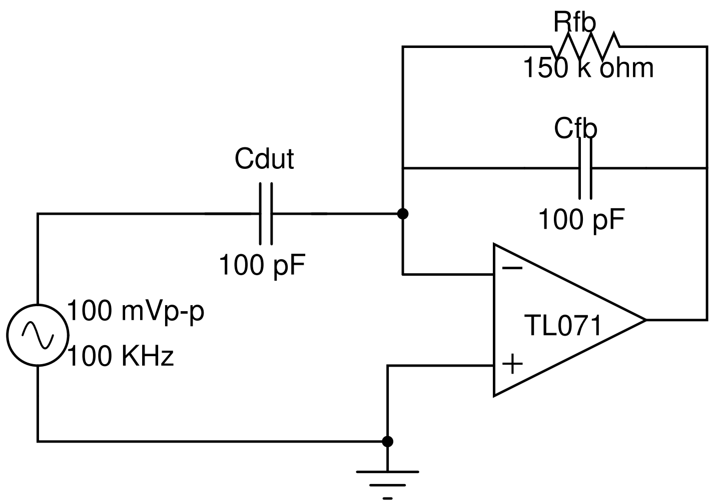
2.2.2 Theory

Since the summer circuit contains the operational amplifier with inverting terminal as input to it, so it will provide some dc bias due to 1V and sinusoidal input with inverted sign.
For our particular circuit the V_{out} is given by:

$$V_{out} = (-1 - 0.5 \times sin(2\pi(100 \times 10^3)t))V$$

The output is negative because our Summer circuit is inverting.

2.2.3 Part 2: Amplifier Circuit:



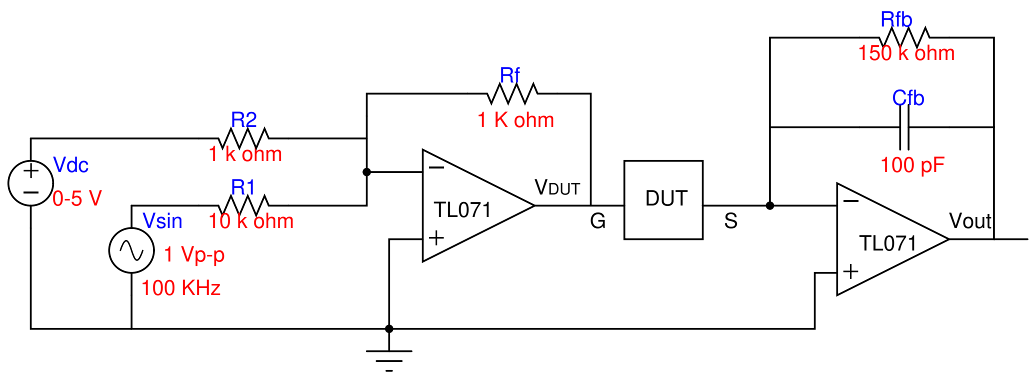
a.) Make the circuit shown above using the Opamp and the other given components.

b.) Observe the output of the Amplifier circuit for different inputs and check if the outputs agree with theory.

2.2.4 Theory

In this part we are using amplifier circuit which is used to amplify input voltage this circuit will act as an amplifier for high frequency input and attenuets low frequency.

2.2.5 Part 3: C-V Characteristics of a MOSCAP



- Combine the above two circuits to proceed with this part.
- Now, measure the capacitance of the DUT, C_{DUT} as V_{DC} is varied from 0 to 5V.
- Next, plot the C-V characteristics using the obtained experimental values (Don't forget to invert the resulting graph with respect to the y-axis because of the Opamp configuration).
- Lastly, calculate all the required parameters using the experimental data and the given equations.

2.2.6 Theory

The acronym MOS stands for Metal oxide semiconductor. A MOS capacitor is made of a semiconductor body or substrate, an insulator and a metal electrode called a gate. Practically, the metal is a heavily doped n+ polysilicon layer which behaves as a metal layer. The dielectric material used between the capacitor plates is silicon dioxide (SiO_2). The metal acts as one plate of the capacitor and the semiconductor layer which may be n-type or p-type acts as another plate.
The capacitance of the MOS capacitor depends upon the voltage applied on the gate terminal. Usually the body is grounded when the gate voltage is applied. The flat band voltage is an important term related to the MOS capacitor. It is defined as the voltage at which there is no charge on the

capacitor plates and hence there is no static electric field across the oxide. The given equations for calculating the required parameters are:

- $$t_{ox} = \frac{A\epsilon_{ox}}{C_{ox}}$$
- $$t_{dep} = 2\sqrt{\frac{\epsilon_{si}}{qN_A}\frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)}$$
- $$C_S = \frac{A\epsilon_{si}}{t_{dep}}$$
- $$C_{min} = \frac{C_{ox}C_S}{C_{ox} + C_S}$$
- $$C_{debye} = \frac{A\epsilon_{si}}{L_{debye}}$$
- $$L_{debye} = \sqrt{\frac{\epsilon_{si}}{qN_A}\frac{kT}{q}}$$
- $$C_{fb} = \frac{C_{ox}C_{debye}}{C_{ox} + C_{debye}}$$

Flat band voltage is the voltage corresponding to flat band capacitance in the C-V curve.

3 Experimental results

3.1 Part 1: Summer Circuit:

The outputs obtained on the DSO were as predicted by theory.

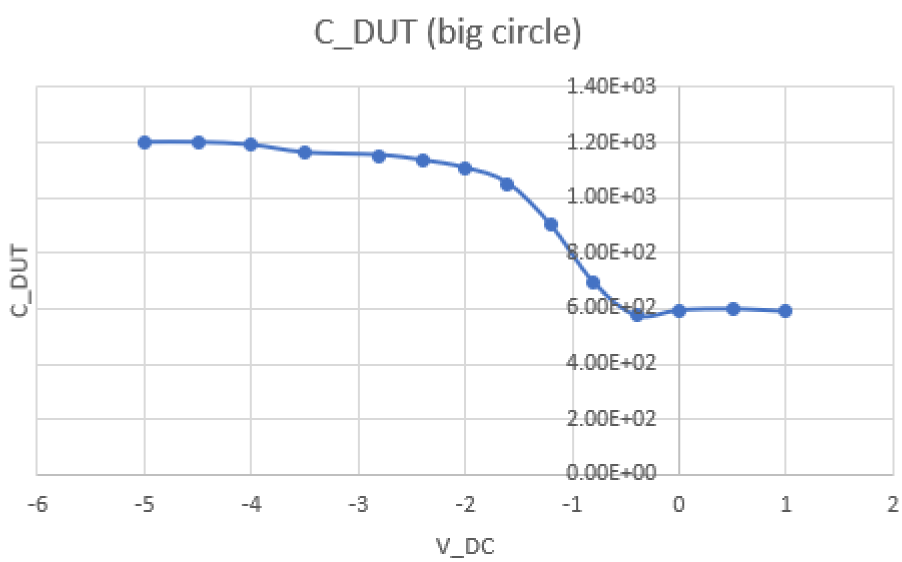
3.2 Part 2: Amplifier Circuit

In this part also the outputs obtained on the DSO were similar to as predicted by theory.

3.3 Part 3: Measurement of MOSCAP C-V Characteristics

I took the square MOSCAP of $2mm$ side length for this experiment.

The C-V characteristics (C_{DUT} vs V_{DC}) plotted from the above data is given below:



3.4 Part 4: Measurement of required parameters of MOSCAP

The calculated parameters are as follows:

Parameters	Values
Oxide Capacitance	1.2 nF
Oxide Thickness	108.3 nm
Doping Density	$1.57 \times 10^{15} cm^{-3}$
Flat Band Voltage	1.7 V
Flat Band Capacitance	0.345 nF
Debye Length	83 nm
Debye Capacitance	0.124 nF

4 Experiment completion status

I have completed all the sections of the Lab and have calculated all the parameters of device which were asked to do in the hand-out of this experiment. Also, during hands-on experiment all the outputs were verified by the TA.