MOS Capacitor C-V Characteristics

Electronic Devices Lab : Experiment 7

Department of Electrical Engineering
Indian Institute of Technology, Bombay
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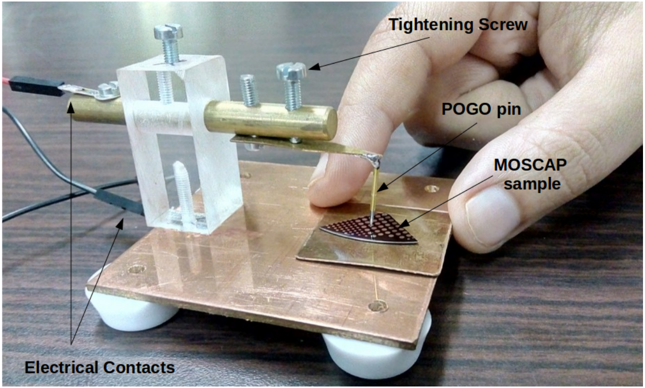
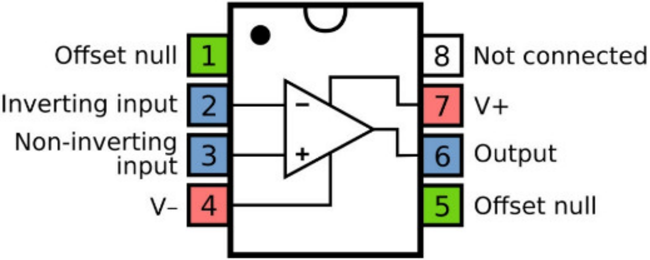
Think it. Make it. Prove it.

Experiment set-up



The top electrical contact which connects to the POGO pin is the gate terminal (G) and the bottom electrical contact is the substrate terminal (S).

TL071 Op-Amp Pinout



TL071 opamp

Precautions

- **Do not touch the sample directly**. Use the copper plate attached to it to handle the sample.
- Probing has to be done carefully since the MOSCAP dimensions are small.
- Make sure the sample is not in contact with the POGO pin while adjusting the sample on the probe station. Also don't over-tighten the POGO pin onto the sample causing scratches on its surface.
- Test the individual circuits (adder and amplifier) first and show it to your TA. Proceed only after both have been verified.

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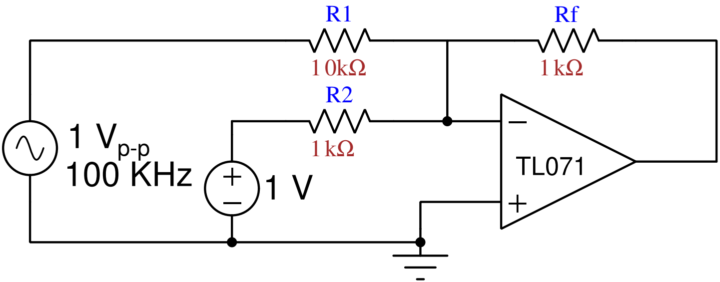
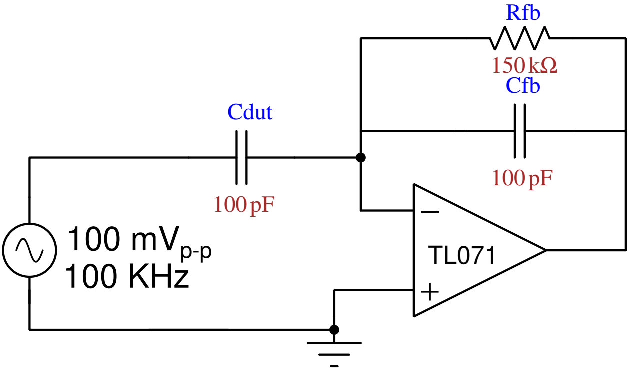
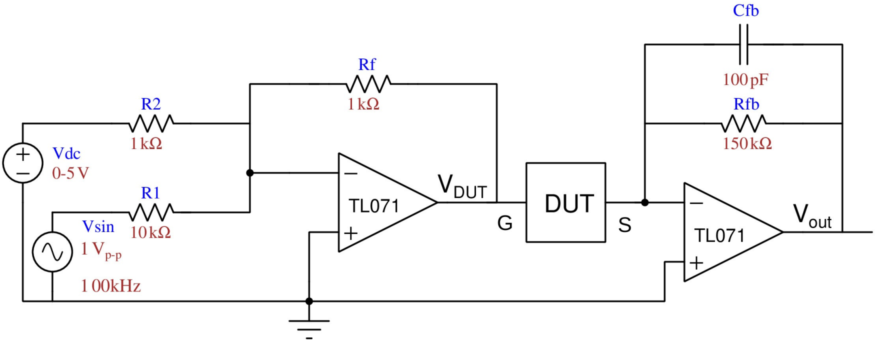
Part I: Summer Circuit



- Recall the working of the summer circuit.
- What do you expect at the output of the above circuit?



- Wire up the above circuit, leaving the previous circuit intact.
- What do you expect at the output of the above circuit?
- Lower the frequency to around 5kHz and observe the output. What can you conclude from your observations?



- Combine the circuit from parts I and II as shown above.
- We have to measure the capacitance of the DUT, C_{DUT} as V_{DC} is varied from 0 to $5V$.
- DUT refers to the MOSCAP sample you are provided.
  G represents gate terminal and S represents substrate.

Part III: Measurement of MOSCAP C-V characteristic

For the above circuit, the AC gain from V_{DUT} to V_{out} is given by,

$$\left|\frac{V_{out\ p-p}}{V_{DUT\ p-p}}\right| = \frac{C_{DUT}}{C_{fb}} \frac{1}{\sqrt{1 + \frac{1}{\left(\omega R_{fb} C_{fb}\right)^2}}}$$

- Set V_{DC} to $0V$. From the observed value of the gain, find C_{DUT}.
- Vary the DC voltage in steps while tabulating the following.

V_{DC}	$V_{DUT\ p-p}$	$V_{out\ p-p}$	AC gain	C_{DUT}

- Take readings till the Op-Amp saturates.
- After taking readings for positive values of V_{DC}, change its polarity and take readings for negative values of V_{DC} as well.

Part III: Measurement of MOSCAP C-V characteristic

Plot C_{DUT} vs V_{DC} from the above table and obtain the following:

- Oxide capacitance
- Oxide thickness
- Doping density
- Flat band voltage
- Flat band capacitance
- Debye length
- Debye capacitance

Note : When V_{DC} is positive, you get negative part of the C-V curve and vice versa (this is due to the Op-Amp configuration). Hence plot accordingly.

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Required Data and Equations

There are 4 different MOSCAPs in each sample and each MOSCAP has different dimensions.

- Circular MOSCAP of $1mm$ diameter
- Circular MOSCAP of $2mm$ diameter
- Square MOSCAP of $1mm$ side length
- Square MOSCAP of $2mm$ side length

Area (A) of the MOSCAP you are dealing with has to be calculated accordingly.

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Required Data and Equations

Intrinsic carrier concentration of Silicon, $n_i = 1.5 \times 10^{10}\ cm^{-3}$.

Thickness of oxide layer is given by,

$$t_{ox} = \frac{A\ \epsilon_{ox}}{C_{ox}}$$

Equation to calculate doping density:

$$t_{dep} = 2\sqrt{\frac{\epsilon_{si}}{qN_A}\frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)}$$

$$C_s = \frac{A\ \epsilon_{si}}{t_{dep}}$$

$$C_{min} = \frac{C_{ox}C_s}{C_{ox} + C_s}$$

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Required Data and Equations

Debye capacitance:

$$C_{debye} = \frac{A\epsilon_{si}}{L_{debye}}$$

Debye length:

$$L_{debye} = \sqrt{\frac{\epsilon_{si}}{qN_A}\frac{kT}{q}}$$

Flat band capacitance:

$$C_{fb} = \frac{C_{ox}C_{debye}}{C_{ox} + C_{debye}}$$

Flat band voltage:
Voltage corresponding to flat band capacitance in C-V curve.