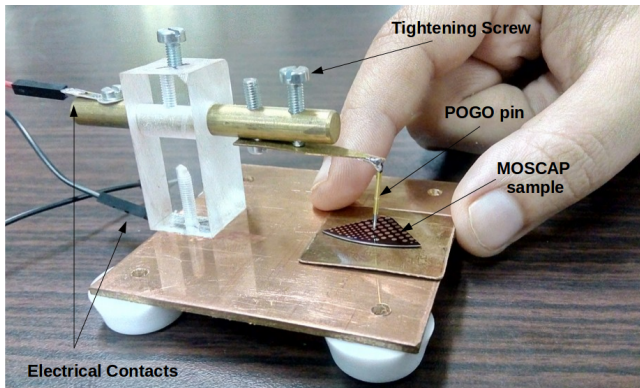


# MOS Capacitor C-V Characteristics

## Electronic Devices Lab : Experiment 7

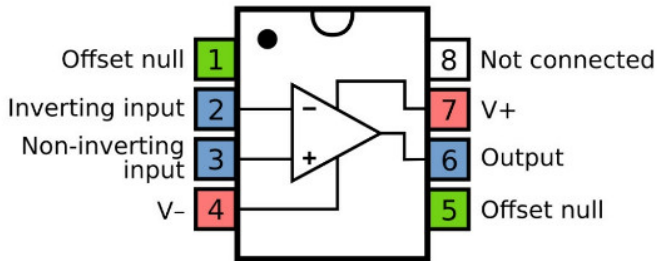
Department of Electrical Engineering  
Indian Institute of Technology, Bombay  
July 5, 2022.

# 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).

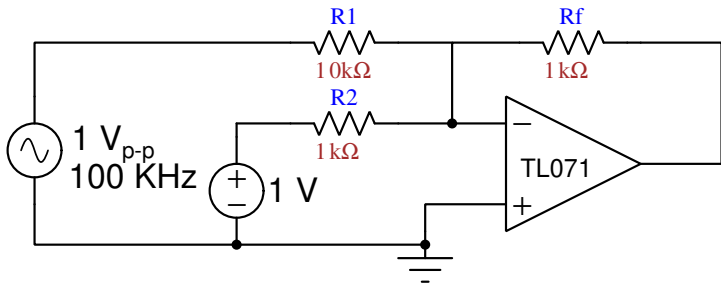
# TL071 Op-Amp Pinout



TL071 opamp

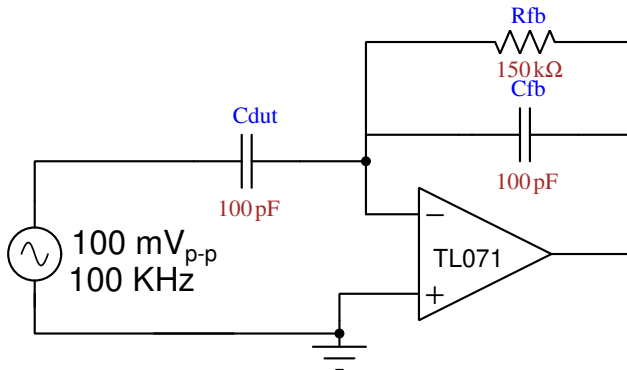
- **Do not touch the sample directly.** Use the copper plate attached to it to handle the sample.
- Probing has to be done carefully since the MOSCAP dimensions are small.
- Make sure the sample is not in contact with the POGO pin while adjusting the sample on the probe station. Also don't over-tighten 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.

# Part I: Summer Circuit



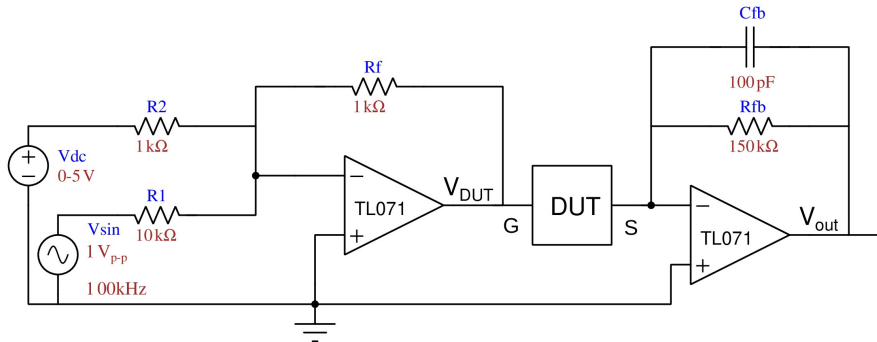
- Recall the working of the summer circuit.
- What do you expect at the output of the above circuit?

## Part II: Amplifier 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?

# Part III: Measurement of MOSCAP C-V characteristics



- 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,

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

- 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.

$V_{DC}$	$V_{DUT \text{ } p-p}$	$V_{out \text{ } p-p}$	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.

# Required Data and Equations

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

- Circular MOSCAP of  $1\text{mm}$  diameter
- Circular MOSCAP of  $2\text{mm}$  diameter
- Square MOSCAP of  $1\text{mm}$  side length
- Square MOSCAP of  $2\text{mm}$  side length

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

# Required Data and Equations

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

Thickness of oxide layer is given by,

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

Equation to calculate doping density:

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

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

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

# 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.