C-V Characteristics of Solar cell

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The Problem Statement

In this experiment, we will do the following:

⇒ Test an opamp based simple circuit for measurement of CV characteristics

⇒ Measure the C-V characteristics of Solar Cell and estimate the doping concentration and built-in potential of the solar cell.

What You Will Need

Before starting the experiment, ensure that you have

- ⇒ Solar Cell Unit
- ⇒ TL071 Operational Amplifier
- ⇒ Resistors- 1 kΩ, 10 kΩ
- ⇒ Capacitor- 0.1 uF and 4.7nF
- ⇒ Multimeters (two), a function generator, a DC power supply
- ⇒ Breadboard and connecting wires (but of course!)

C-V Characteristics of a Solar Cell

⇒ When reversed biased, a PN junction exhibits capacitance C_j. The value of capacitance depends upon the applied reverse bias.

⇒ In this experiment, we intend to measure this capacitance, its voltage dependence and estimate doping profile of a PN junction, using a very low cost instrumentation.

⇒ The PN junction under consideration is that of a solar cell. (Why ?)

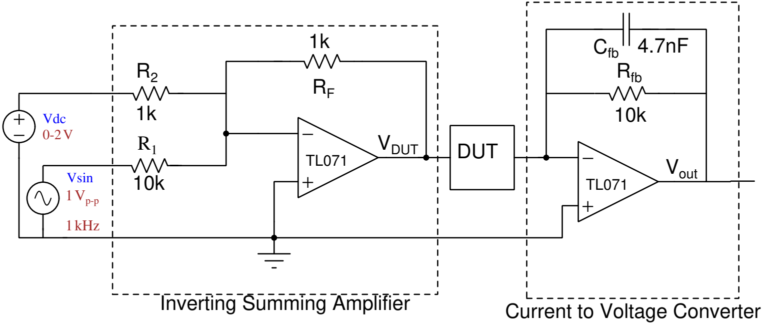
C-V Characteristics of a Solar Cell (cont'd...)

⇒ This can be achieved by applying a reverse bias to the diode so that it acts as a capacitor.

⇒ To estimate the capacitance value, a small AC signal is superimposed on this DC reverse bias using a summing amplifier, and the AC current through the capacitor is measured (by converting it to voltage - *why ?).

* We need to ensure that the device functions as a capacitor. This is done by ensuring the phase shift between the voltage applied to the capacitor and the current through the capacitor to be 90^0.

Measurement of capacitance of solar cell

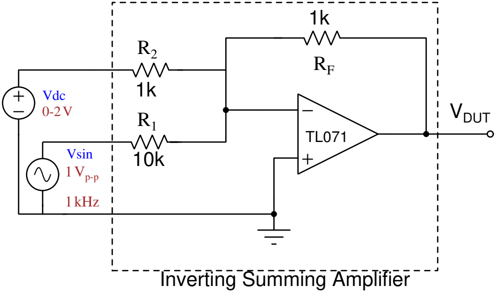


Note : DUT = Device Under Test

⇒ This is the circuit for the measurement of capacitance.

⇒ Don't connect the entire circuit. We will do it in parts.

Part A : Inverting Summing Amplifier



⇒ Figure shows inverting summing amplifier. Let V_{ac} be of 1 V_{pp} amplitude and 1KHz frequency.

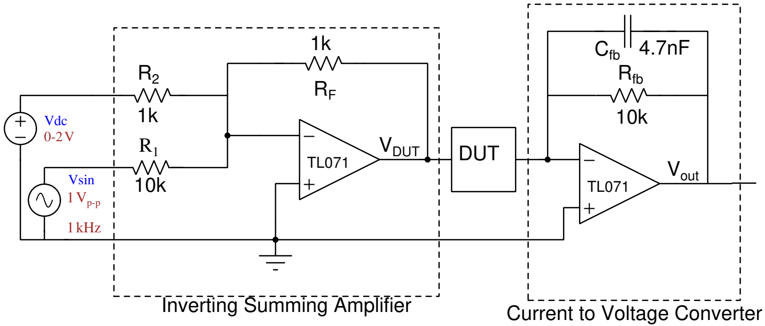
⇒ Derive the equation for the output V_{DUT}.

Part A : Inverting Summing Amplifier (Cont'd...)

Procedure:

1. Wire up the circuit as shown. Switch on the $+V_{cc}$ and $-V_{cc}$ supply before giving the inputs.
2. Now adjust the DC level input V_{dc} to 1 V.
3. Adjust V_{ac} : AC voltage level to Sine wave of 1 V_{pp} and a frequency of 1 kHz (without any DC offset).
4. Observe the output of the operational amplifier with respect to input. Sketch these waveforms in your report.
5. Measure and label the AC and DC components of the input and output waveform.
6. What is the gain of the circuit for V_{ac} and V_{dc} inputs ?

Part B : Measurement of unknown Resistor



⇒ Current to voltage converter will convert the current flowing through $R_{unknown}$ to output voltage across R_{fb}.

⇒ Derive the equation for $R_{unknown}$ in terms of V_{out}, V_{DUT}, and R_{fb}.

Part B : Measurement of unknown Resistor (Cont'd...)

Procedure:

1. Now connect the Current to voltage converter circuit.
2. Connect 1 kΩ resistor as $R_{unknown}$.
3. Observe V_{out} with respect to V_{DUT} and sketch in your report. Observe the phase difference.
4. Can you estimate the value of $R_{unknown}$ from the equation you derived. It should be 1 kΩ.

This means our circuit is working!

Part C : Measurement of unknown Capacitor

- Now let's see how the same circuit can be used to estimate capacitance.

$\Rightarrow$ Now connect a capacitor as DUT.

$\Rightarrow$ Derive the equation for $C_{unknown}$ in terms of V_{out}, V_{DUT}, and R_{fb}.

Part C : Measurement of unknown Capacitor (Cont'd...)

Procedure:

1. Now we will use a 0.1 uF capacitor as DUT : $C_{unknown}$.
2. Observe V_{out} and V_{DUT} on CH1 and CH2 of the DSO. Sketch/paste the picture of these waveforms in your report.
3. What is the phase difference between V_{out} and V_{DUT} ? It should be 90^0.
4. From the output voltage V_{out} estimate the value of the capacitor $C_{unknown}$. It should be 0.1 uF.

This means the circuit can be used to measure unknown capacitance !

Part D : C-V Characteristics of Solar Cell

⇒ Now in this part, we use solar cell as DUT.

⇒ We will make the measurements in "Dark", So do not apply any voltage to LED bank.

⇒ Negative DC component of V_{DUT} ensures -ve voltage at the anode of the cell and with cathode held at ground potential,the cell gets reverse biased. Recall virtual ground concept in Op-Amp.

Part D : C - V Characteristics of Solar Cell (Cont'd...)

Procedure:

1. Set the frequency to be 1 kHz. Measure the phase difference.
2. The phase difference should be close to 90^0. This indicates that the solar cell behaves like a capacitor.
3. Vary the DC voltage increments to measure the capacitance values at each bias voltage.

Why does the capacitance vary as a function of applied Voltage?

Tips for phase Measurement :

$\Rightarrow$ Adjust the input frequency (Around 1 kHz) to get more clear waveform on the CRO Screen. Don't forget to use the same one in calculations.

$\Rightarrow$ It's advised to use the time domain method to calculate the phase difference and reduce errors.

Formulae

Output of the Summing Amplifier :

$$V_{DUT} = -R_F(\frac{V_{dc}}{R_2} + \frac{V_{ac}}{R_1}) \tag{1}$$

Output of current to voltage converter:

$$V_{out} = V_{DUT}(\frac{-Z_{fb}}{Z_{DUT}}) \tag{2}$$

$$Z_{fb} = R_{fb}||X_{cfb}$$

$$\text{Z}_{DUT} = R_{unknown} \text{ if DUT is a resistor}$$

$$Z_{DUT} = \frac{1}{j\omega C_{DUT}} \text{if DUT is a capacitor}$$

Obtaining Results and Interpreting Them

⇒ Part A : Verify the output of summing amplifier.

⇒ Part B : V_{DUT} = ?, V_{out} = ?, $R_{unknown}$ = ?

⇒ Part C : V_{DUT} = ?, V_{out} = ?, $C_{unknown}$ = ?

⇒ Part D : Plot ($\frac{1}{C^2}$) Vs. V_{dc} and get doping concentration and built in voltage (see the writeup) .