Diodes Transients & C-V Characteristics of Schottky Diode

Electronic Devices Lab : Experiment 2

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Aim of the experiment

- To measure and compare the reverse recovery times of a P-N Junction diode (1N4007) and a Schottky diode (1N5822).
- To measure C-V characteristics of a Schottky diode and extract its built-in potential and doping density.

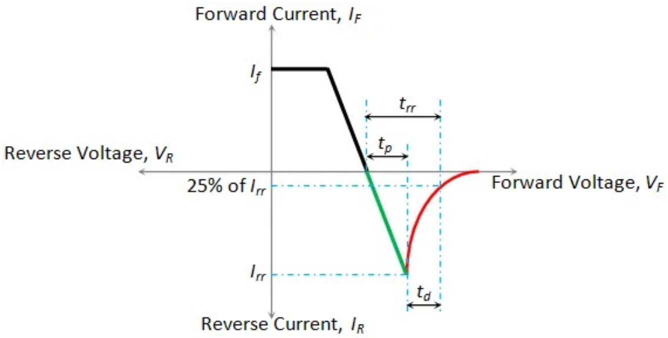
Theory - Reverse Recovery Time

- When a diode is switched from forward to reverse bias, ideally it should switch instantly and block any current flow. But in reality, a reverse current will flow for a short period of time.
- This is caused due to stored charge in the junction, which takes time to recombine.
  Reverse recovery time of the diode is the time gap between the instant at which the reverse current starts to flow through the diode to the time instant at which it reaches to 0 (or some predefined value close to 0).
- It can be a significant source of loss in switching regulations. But it can also be beneficial in some signal switching applications.
  (like PIN diode for RF switching)

Think it. Make it. Prove it.

Theory - Reverse Recovery Time

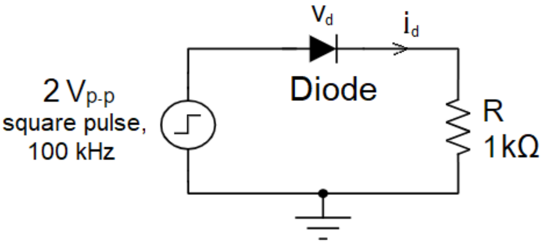
The below figure illustrates what happens when the polarity of voltage across diode is switched.



I_{rr} is the peak reverse current. Here, the RRT is measured till when the reverse current reaches 25% of I_{rr}.

Procedure - Reverse Recovery Time

Rig up the circuit given below (first for PN junction diode and then for Schottky diode). Apply square wave of amplitude 2 V p-p (the amplitude can be increased if needed) and varying frequencies.



Observe the output and note down the readings in the following format. Try to explain the difference in RRTs of the PN and Schottky diodes.

Frequency	RRT of PN	RRT of Schottky
10 kHz		
100 kHz		
1 MHz		
10 MHz		

C-V Characteristics of Schottky Diode

- The C-V characteristics of a reverse biased Schottky diode can be used to determine its built-in voltage V_{bi} and doping density N_d.
- The capacitance of a Schottky diode can be represented by:

$$\frac{1}{C^2} = \frac{2(V_{bi} - V_i)}{q\epsilon_s\epsilon_o S^2 N_d}$$

  (S is the area of cross-section)
- Notice that the above equation represents a straight line. N_d can be calculated using the slope whereas V_{bi} can be calculated using the intercept.

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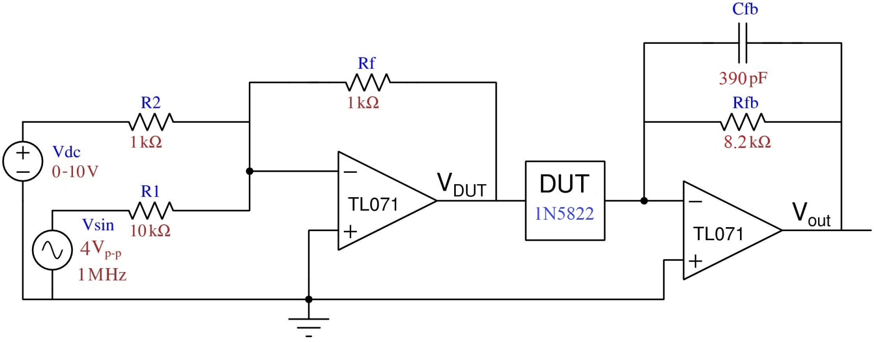
Measurement of Schottky C-V characteristics

A summer circuit followed by a filter circuit (using Op-Amps) is used to measure the C-V characteristics.



- The capacitance of the DUT, C_{dut} is to be measured as V_{dc} is varied from $0V$ to $10V$.

DUT refers to the Schottky diode you are provided with.
The Schottky diode must be reverse biased.

Measurement of Schottky Diode C-V characteristics

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

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

- Set V_{dc} to $0V$. From the observed value of the gain, find C_{dut}.
- Vary the dc voltage in steps while tabulating the C_{dut} and the applied DC voltage.
- Plot C_{dut} vs V_{dc} and observe the trend.

Think it. Make it. Prove it.

TL071 Op-Amp Pinout

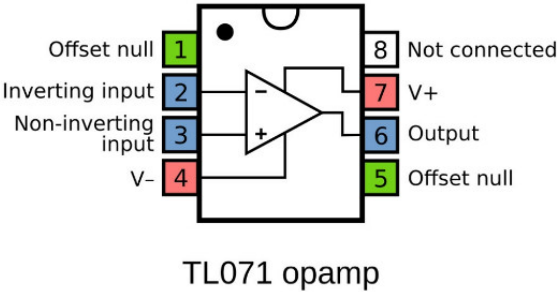


Figure: Pin diagram of Op-Amp for reference

Calculating Doping Density and Built-in Potential

- Plot $1/C_{dut}^2$ vs V_{dc}. This graph will be used to extract the required quantities.
- Calculate the slope and x-intercept of $1/C_{dut}^2$ vs V_{dc} curve.
- The built-in potential (V_{bi}) will be equal to the magnitude of x-intercept.
- To find the doping density, use:

$$Slope = -\frac{2}{q\epsilon_s\epsilon_o S^2 N_d}$$

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Calculating Doping Density and Built-in Potential

To calculate area, use the reverse current equation.

$$I_{rev} = SA^* T^2 e^{-V_{bi}/V_t}$$

- A^* is the Richardson's constant, which is equal to 110 $A/K^2 cm^2$.
- I_{rev} (reverse current) for the Schottky diode is 4 uA.
- Absolute temperature (T) is of course the room temperature and can be taken as 300 K and the thermal voltage (V_t) at room temperature will be 0.026 V (or 26 mV).

Using these quantities, the area S of the Schottky diode has to be extracted in order to find the doping density (from the formula given in the previous page).

Note : Perform all calculations in terms of cm, there is no need to convert anything to m.

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Post-lab Simulation Exercise

- Write an NGSPICE net-list to implement full-wave bridge rectifier using regular P-N junction diode (1N4007).
- Apply a sinusoidal signal (50 Hz frequency, 10 V p-p amplitude) and plot the output and the transfer characteristics.
- Perform the same experiment using Schottky diode (BAT85) and observe the results.
- Which of the 2 diodes is a better rectifier and why?

Think it. Make it. Prove it.