EE236: Experiment 6
Minority carrier lifetime measurement

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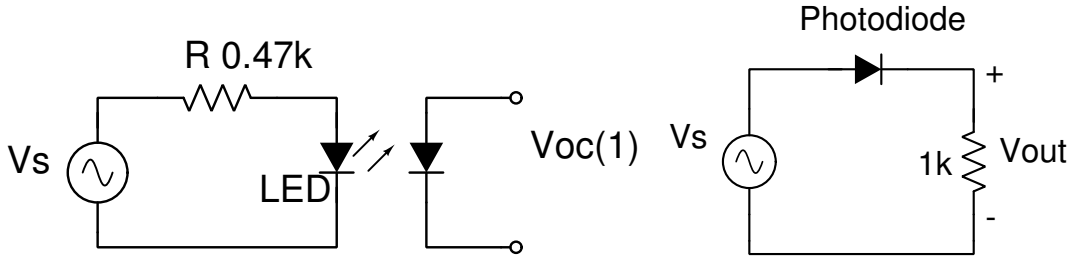
1 Aim of the experiment

We make use of two distinct techniques to measure minority carrier lifetime in semiconductor photodiode.

- Observe voltage decay with time by shining and removing light on the sensor.
- Provide a waveform with different forward and reverse biases and plotting a graph between them

2 Methods



(a) Circuit for Part 1

(b) Circuit for Part2

Photodiode is connected through a resistor in series. The circuit is provided voltage from a function generator which is set to provide square-wave input of varying frequencies.

2.1 Part 1

LED is provide 5V continuous pulses from function generator emitting light pulses. The light pulses fall on the open circuited photodiode placed beside. We adjust the input wave frequency so that transient is properly revealed. The corresponding waveform is observes on the Digital Storage Oscilloscope and the life time is calculated by the formula given.

$$V_{oc}(t) = A - \frac{kT}{q}\frac{t}{\tau_0}$$

Hence, we then calculate the minority carrier lifetime τ_0 using slope of linear region in transient.

2.2 Part 2

We adjust the value of DC offset in function generator for different values of V_1 and V_2. The data is recorded for different DC offsets at 3 different frequencies which are 1 kHz, 40 kHz, and 100 kHz. The data consists of voltage across resistor and use it to find storage time τ_s. This data will be used to plot graph and estimate τ_0.

3 Observations

3.1 Part 1

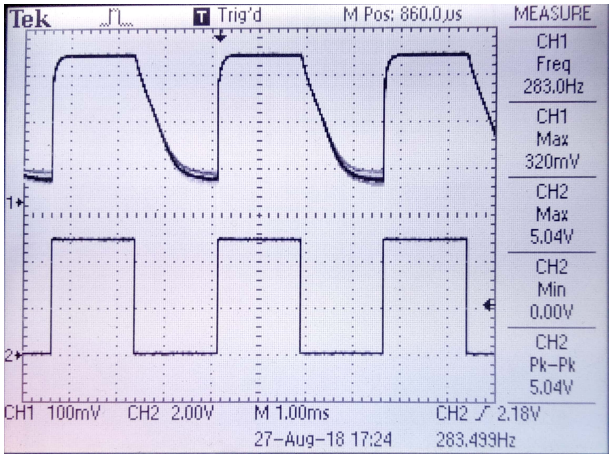
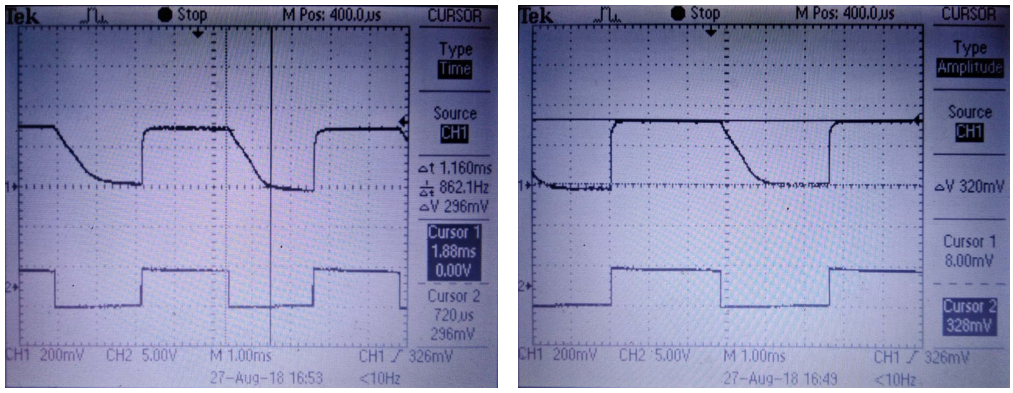


Figure 1: V_{oc} : Photodiode's response to 5V Pulses

We can clearly see the almost linear voltage decay as soon as the light turns off. We obtain the above waveform on providing 5V pulses to the LED and calculated slope of linear region.



(a) Δt measurement (b) ΔV measurement

Figure 2: Cursor Measurement

Δt in ms	ΔV in mV
1	277
1.02	280
1.04	284
1.08	296
1.12	310
1.15	318

Table 1: Recorded Values of Linear Regions

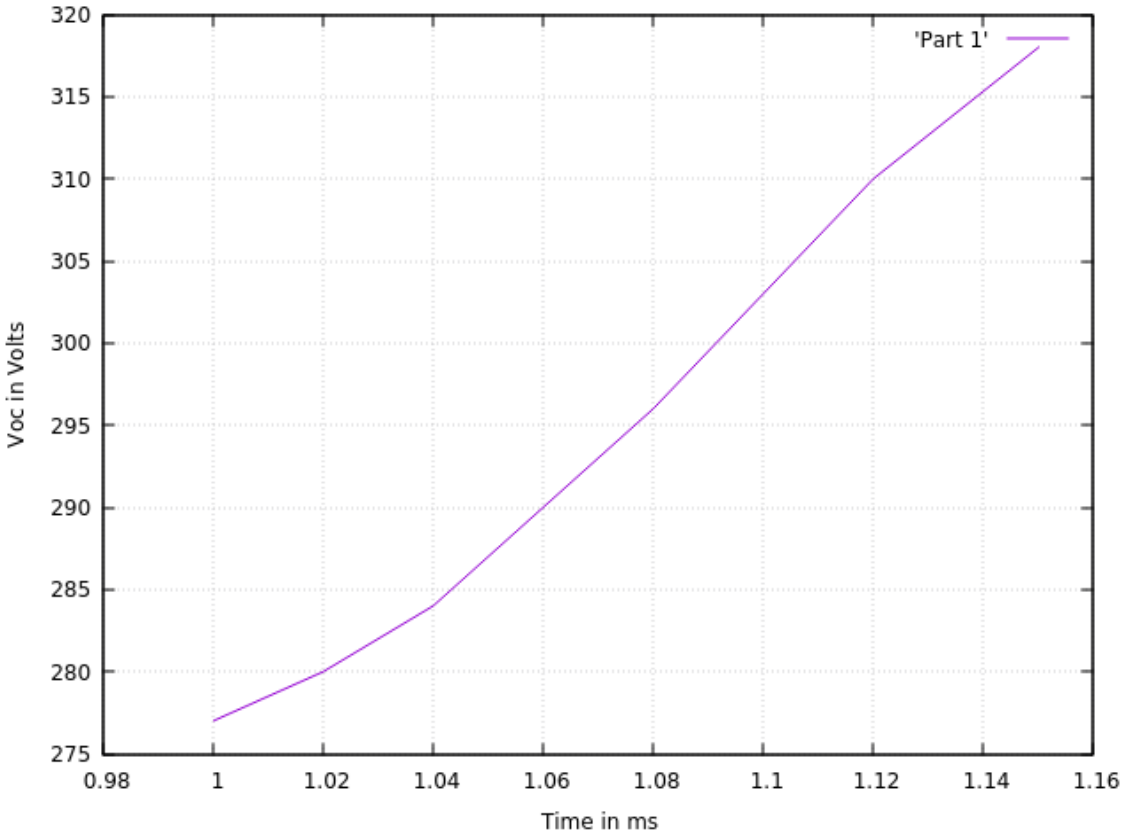
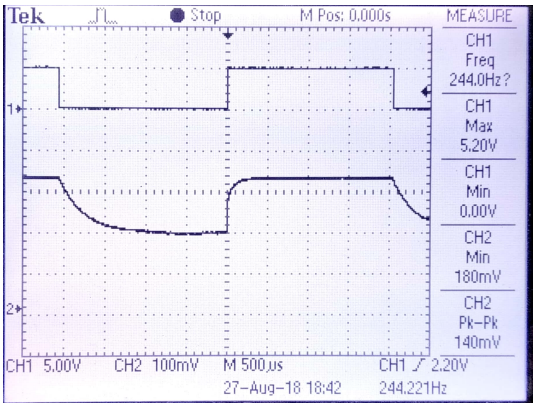


Figure 3: Voltage drop in decay vs time taken in linear region of decay

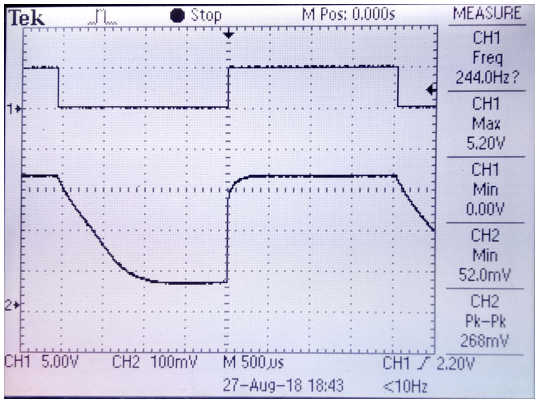
From the above plot, we can find minority carrier life time by finding the slope of best fit line.

$$\tau_0 = \frac{0.0256}{Slope} = \frac{0.0256}{285.342} = 89.7\mu s$$

Now, the next subpart asks what happens when LED and Photodiode are uncovered i.e. tape is removed.



(a) Waveform with diode uncovered



(b) Waveform with diode covered

Figure 4: Side by side comparison of waveforms with diode uncovered and covered

3.2 Part 2

(total 8 marks) Note down observations, not inferences. Add all screenshots you recorded (4 marks). If you faced technical challenges in performing the experiment, list them out in t

V1	V2	Time
2.4V	-4V	23 μs
3V	-3.6V	36 μs
4.5V	-2V	64 μs
6V	-0.6V	176 μs

(a) 1kHz

V1	V2	Time
2.4V	-4V	2.2 μs
4.5V	-2V	12.3 μs
3.6V	-3V	5.5 μs

(b) 40kHz

V1	V2	Time
2.5V	-3V	1.4 μs
4V	-4V	1.7 μs
5V	-3V	4.9 μs

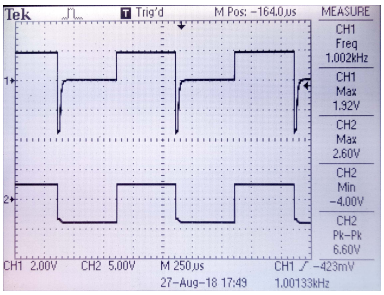
(c) 100kHz

Figure 5: Data for storage time for different V_1 and V_2

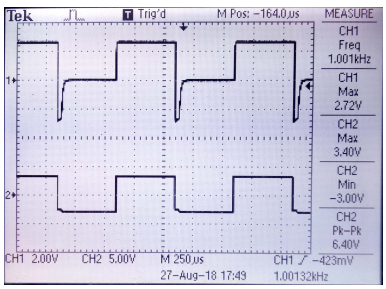
4 Inference

4.1 Part 1

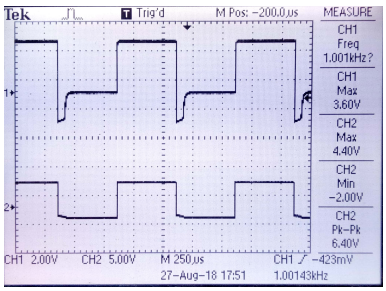
(4 marks) Note down inferences drawn from observations in part 1.



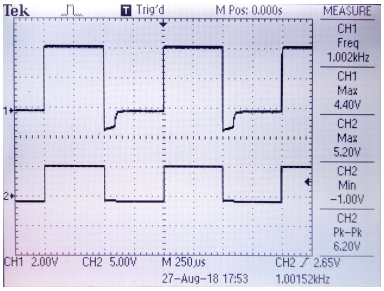
(a) 2.6V, -4V, 1kHZ



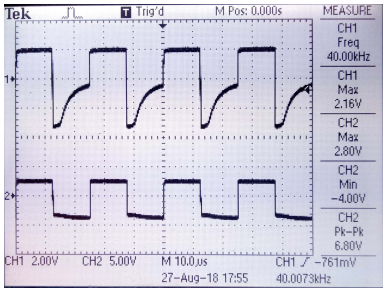
(b) 3.4V, -3V, 1kHZ



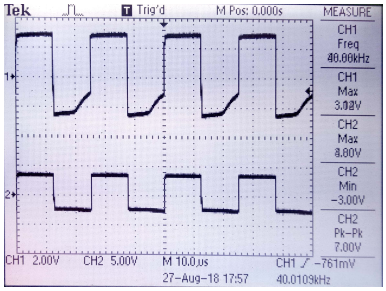
(c) 4.4V, -2V, 1kHZ



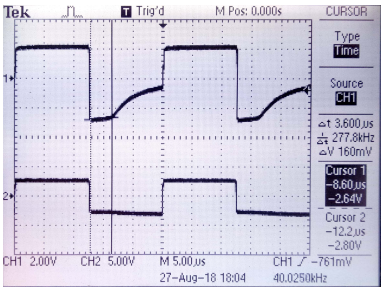
(d) 5.2V, -1V, 1kHz



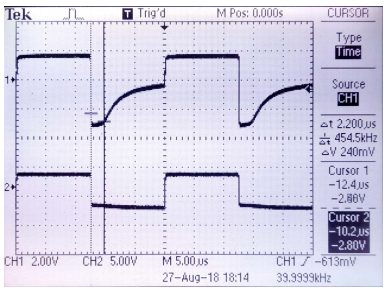
(e) 2.8V, -4V, 40kHz



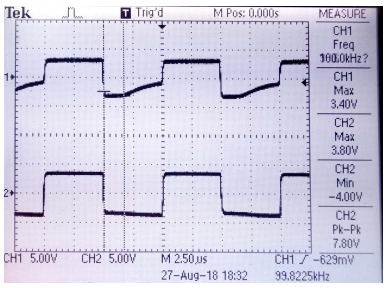
(f) 3.8V, -3V, 40kHz



(g) 40kHZ, Measurement



(h) 100kHz, Measurement



(i) 100kHz, Measurement

Figure 6: DSO Screenshots of waveform and τ_s measurements

4.2 Part 2

(4 marks) Note down inferences drawn from observations in part 2.

5 Reflection questions

(ungraded)

1. In part-2, when the square wave siwtches from positive half cycle to negative half cycle, is the diode in forward bias or reverse bias during the storage time duration? The voltage applied qualifies the diode as reverse biased, but there is a large current flowing due to excess carriers!! Make sure you ask this question during your EE207 class when they teach you carrier lifetime.
Ans.

2. Based on what you observed during this lab, what do you think is the equivalent circuit of a diode (an equivalent circuit is a simplified circuit that presents the same response as the diode to applied voltage, and is represented in terms of resistors, capacitors, inductors, voltage/current sources, and any other elementary circuit components).
Ans.

3. You used Schottky diode in the last lab. How would you expect the response to be if you used Schottky diode in this experiment in part-2?
Ans.