EE236: Lab 2
Diodes Transients and C-V Characteristics of Schottky Diode

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1 Overview of the experiment

1.1 Aim of the experiment

To measure and compare the reverse recovery times of a P-N Junction diode (1N4007) and a Schottky diode (1N5822) and to measure the C-V characteristics of a Schottky diode to extract its built-in potential and doping density. In post-lab experiment, a full-wave bridge rectifier circuit has been simulated using only P-N Junction diodes (1N4007) and then only Schottky diodes (1N5822).

1.2 Methods

In the first part, Ngspice netlists were written to obtain reverse recovery times (RRTs) of 1N4007 and 1N5822 diodes with 2 V $p-p$ square wave source of 1 kHz, 10 kHz and 100 kHz frequncies and then implementing the same on a breadboard to obtain RRTS of both diodes for various frequencies. In the second part, C-V characteristics of the Schottky diode were obtained to determine its built-in potential (V_{bi}) and doping density (N_d). For the post-lab simulation exercise, a sinusoidal input (10 V_{p-p}, 50 Hz) was given to the full-wave bridge rectifier circuit to compare the output and transfer characteristics of both the diodes.

2 Design

2.1 Part 1

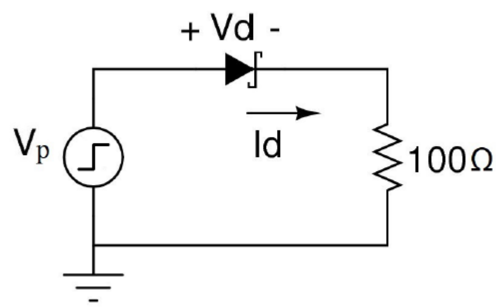


Figure 1: RRT Measurement Circuit

$$R = 1\ k\Omega$$

After implementing the circuit above on a breadboard, t_{rr} was measured by analysing $I_d\ vs\ t$.

2.2 Part 2

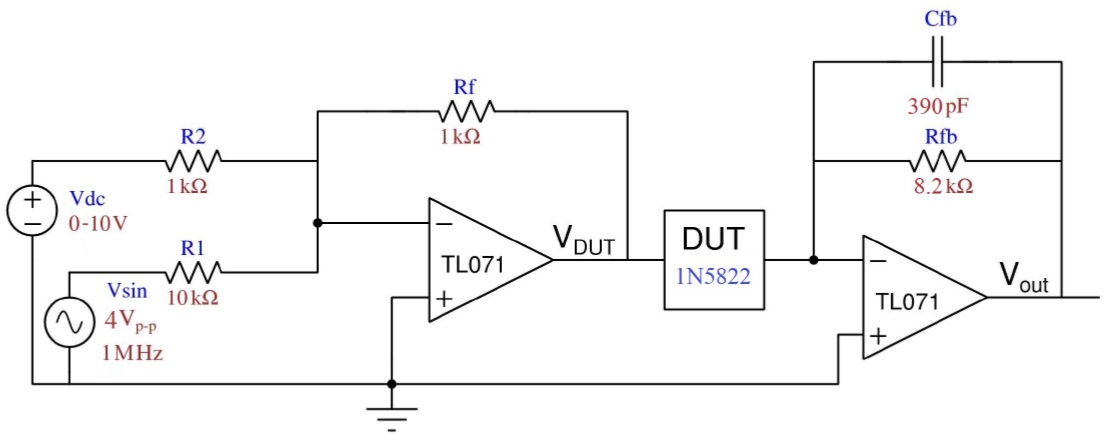


Figure 2: A Summer Circuit followed by a Filter Circuit (using Op-Amps)

$V_{dc} = 0 - 10\ V,\ V_{sin} = 4\ V_{p-p}(1\ MHz)$
$R_1 = 10\ k\Omega,\ R_2 = 1\ k\Omega,\ R_f = 1\ k\Omega,\ R_{fb} = 8.2\ k\Omega$
$C_{fb} = 390\ pF$

V_{out} and V_{dut} were measured as V_{dc} is varied from $0\ V$ to $10\ V$.

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

Plot C_{dut} vs V_{dc}.

$$\frac{1}{C^2} = \frac{2(V_{bi} - V_i)}{q\epsilon_s\epsilon_0 S^2 N_d}$$

Plot $\frac{1}{C_{dut}{}^2}$ vs V_{dc}.

$$|x - intercept| = V_{bi}$$
$$Slope = -\frac{2}{q\epsilon_s\epsilon_0 S^2 N_d}$$

$$I_{rev} = SA^{\,T^2 e^{-\frac{V_{bi}}{V_t}}}$$

2.3 Part 3 (Post-Lab)

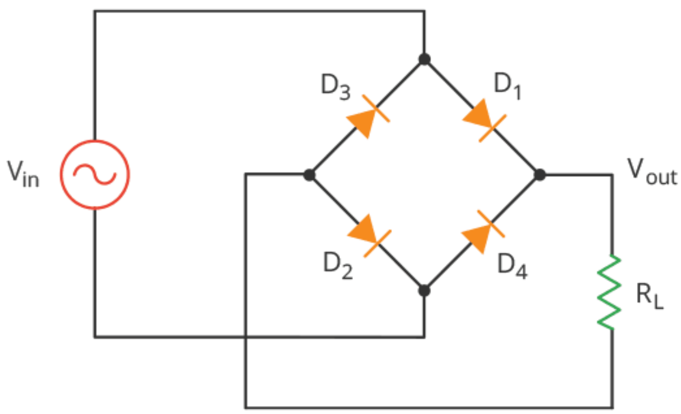


Figure 3: Full-wave Bridge Rectifier Circuit

$R = 1\ k\Omega$
$V_{sin} = 10\ V_{p-p}(50\ Hz)$

3 Simulation results

3.1 Code snippet

Pre-Lab

```
1N4007 Diode
.include 1N4007.txt
vp 1 0 PULSE(-1 1 2NS 2NS 2NS .0005MS .001MS)
d1 1 2 1N4007
r1 3 0 100
v2 2 3 0
.tran .001u .005m
.control
run
```

```
plot v(1, 2) 5+100*i(v2)
.endc

Schottky Diode
.include BAT85.txt
vp 1 0 PULSE(-1 1 2NS 2NS 2NS .0005MS .001MS)
x1 1 2 BAT85
r1 3 0 100
v2 2 3
.tran .001u .005m
control
run
plot v(1, 2) 2.5+100*i(v2)
.endc
```

Post-Lab

```
1N4007 Diode
.include 1N4007.txt
v1 1 0 SINE(0 5 50)
d1 1 3 1N4007
d2 2 1 1N4007
d3 2 0 1N4007
d4 0 3 1N4007
r1 2 3 100
.tran 1u 100m
.control
run
plot v(3,2) v(1)
plot v(3,2) vs v(1)
.endc

Schottky Diode
.include BAT85.txt
v1 1 0 SINE(0 5 50)
x1 1 3 BAT85
x2 2 1 BAT85
x3 2 0 BAT85
x4 0 3 BAT85
```

```
r1 2 3 1k
.tran .1u 60m
.control
run
plot v(3,2) v(1)
plot v(3,2) vs v(1)
.endc
```

3.2 Simulation results

Figure 4: Frequency 1KHz

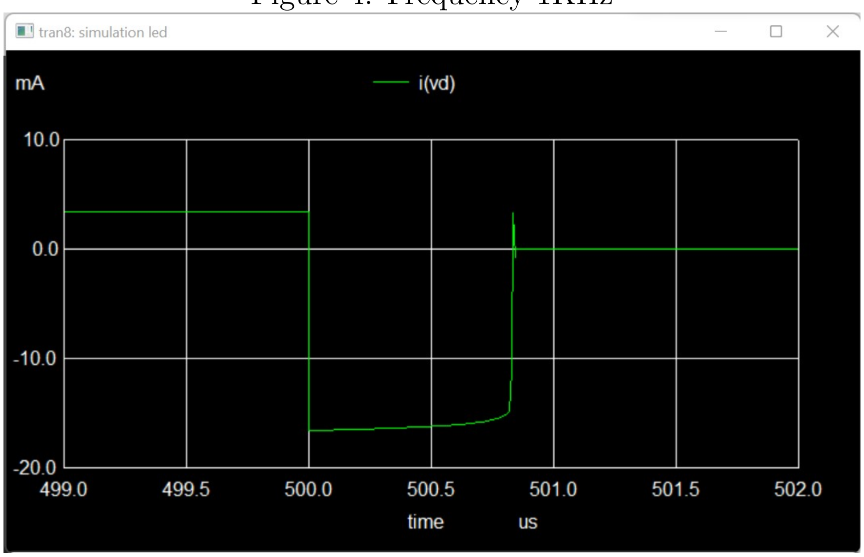


Figure 5: Frequency 10KHz

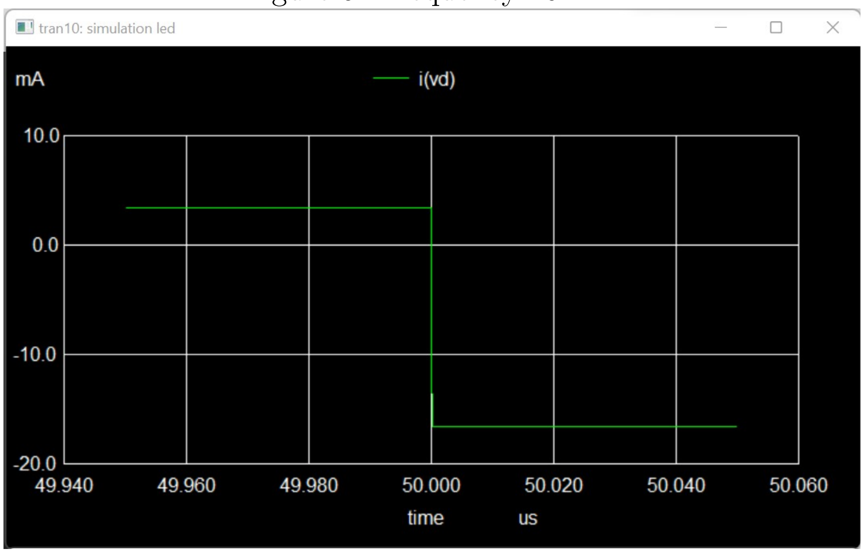


Figure 6: Frequency 100KHz

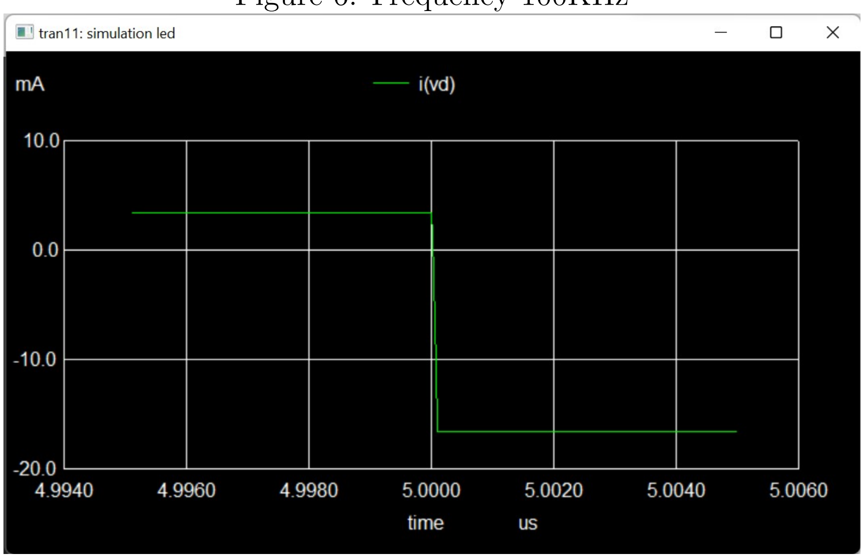


Figure 7: Frequency 1KHz

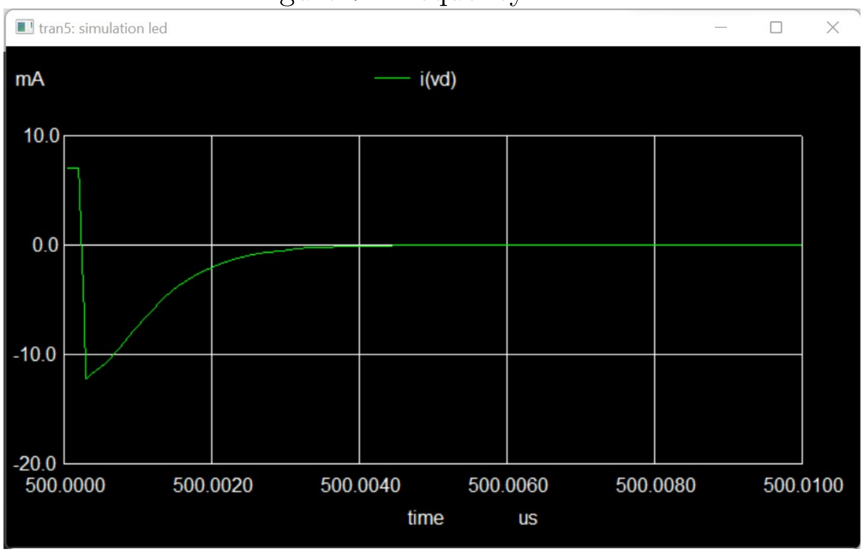


Figure 8: Frequency 10KHz

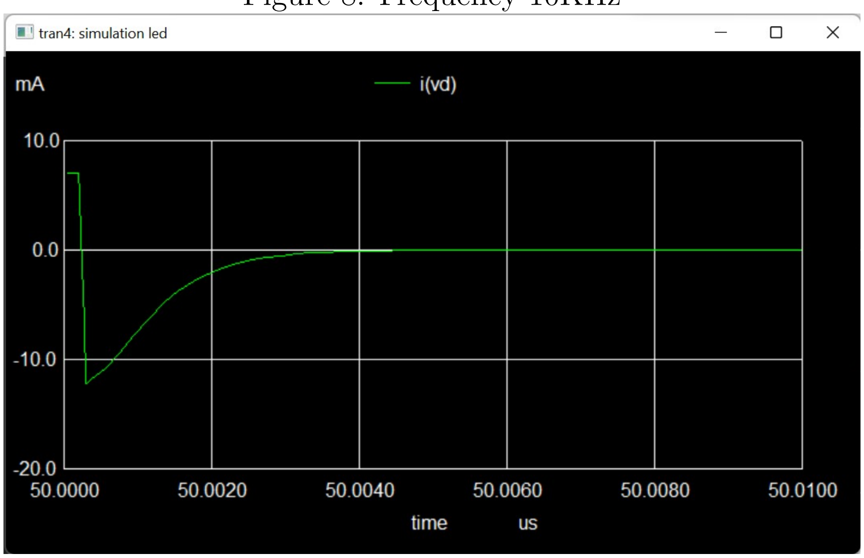
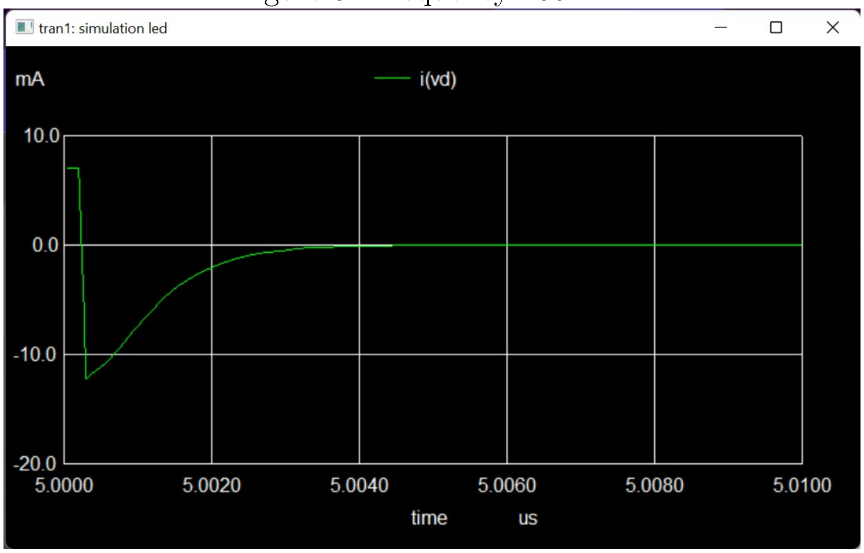


Figure 9: Frequency 100KHz



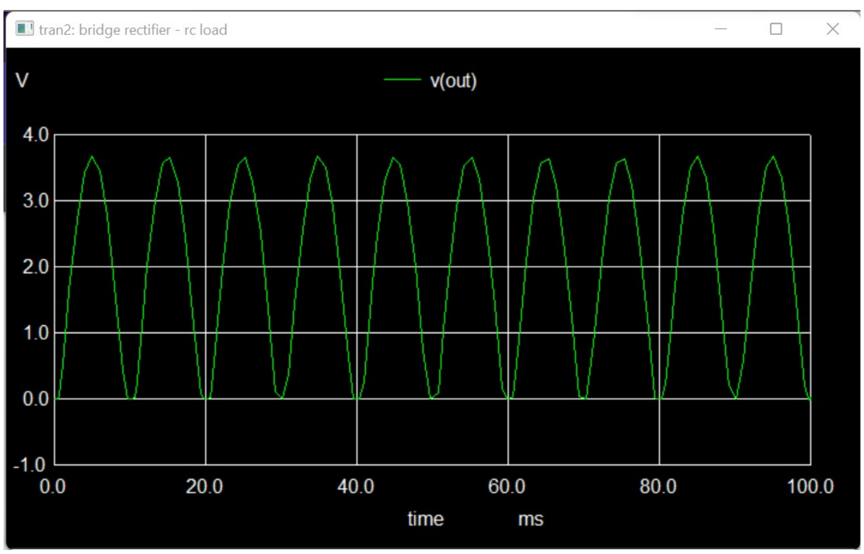


Figure 10: 50 Hz 10 V_{PP} on 1N4007 diode

The Schottky diode (BAT85) has a smaller cut-in voltage compared to the P-N Junction diode (1N4007) and hence, the former forms a better rectifier.

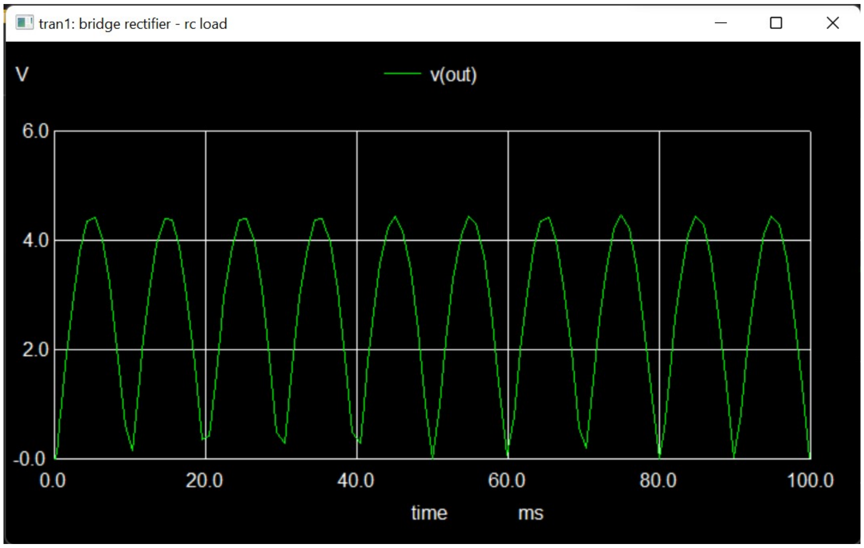


Figure 11: 50 Hz 10 V_{PP} on BAT85 diode

4 Experimental results

4.1 Part 1

P-N Junction diode (1N4007)				
	V_0	25% V_0	T_{rr}	
10K	1.38	0.345	1220	
100K	1.34	0.335	920	
1M	0.664	0.166	470	
10M	Couldn't determine because frequency was too high and V wasn't able to reach 25% of V			
Schottky diode				
	V_0	25% V_0	T_{rr}	
10K	0.576	0.144	660	
100K	0.536	0.134	760	
1M	0.528	0.132	480	
10M	Couldn't determine because frequency was too high and V wasn't able to reach 25% of V			

Figure 12: (t_{rr} is written in μ seconds)

RRT of PN diode decreases significantly with frequency whereas that's not the case with Schottky diode. RRT of PN diode starts decreasing at lower frequencies while RRT of Schottky diode is practically the same.

4.2 Part 2

V_{DC}	V_{OUT} (mV)	V_{DUT} (mV)	C_{DUT} (pF)	$1/C2*10^{-5}$
0.1	510	384	517.9688	3.73E-01
1.1	360	408	344.1176	8.44E-01
2	296	416	277.5	1.30E+00
2.9	264	400	257.4	1.51E+00
3.8	232	480	188.5	2.81E+00
4.8	208	490	165.551	3.65E+00
5.7	192	490	152.8163	4.28E+00
6.9	164	490	130.5306	5.87E+00
7.7	159	510	121.5882	6.76E+00
8	158	510	120.8235	6.85E+00
8.5	126	540	91	1.21E+01
10	22	560	15.32143	2.1E+01

Figure 13: Measurements

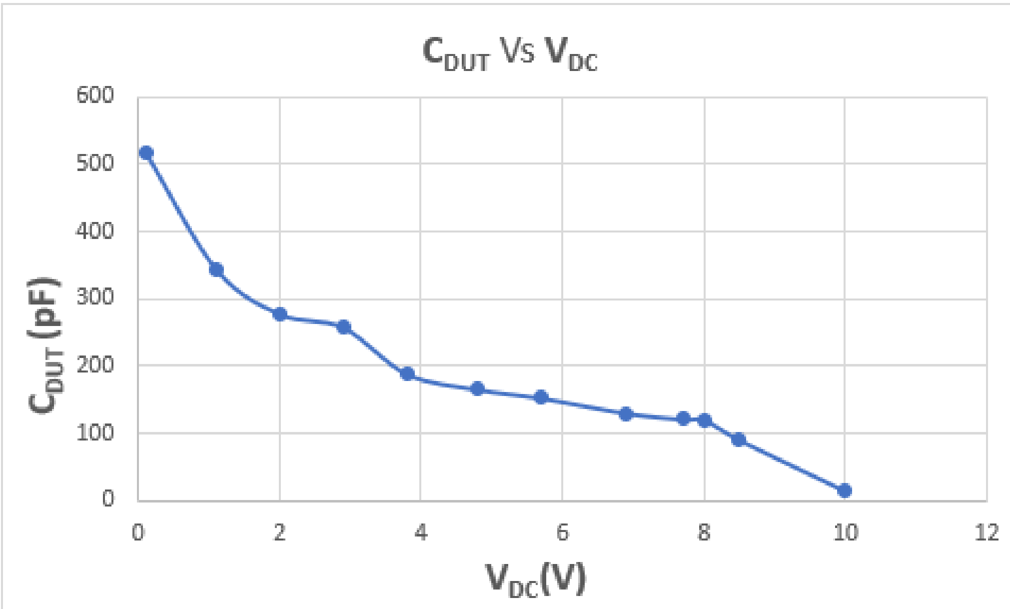


Figure 14: CV Characteristics of Schottky Diode

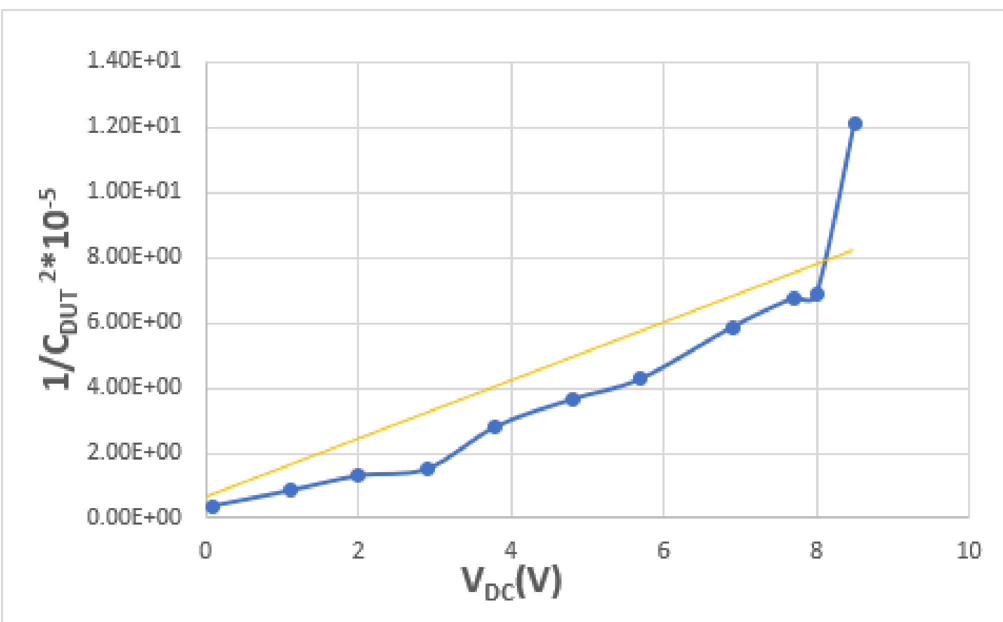


Figure 15: $\frac{1}{{C_{dut}}^2}$ varies approximately linearly with V_{dc}

$$
\begin{aligned}
&x - intercept &&= \ -0.052\ V \\
\implies &V_{bi} = |x - intercept| &&= 0.052\ V \\
\implies &N_d = -\frac{2}{q\epsilon_s\epsilon_0 S^2(Slope)} &&= 2.84 \times 10^{14}\ cm^{-3}
\end{aligned}
$$

5 Experiment completion status

All sections were completed in the lab and shown to the TA.