EE 236: Experiment 3
PIN Diode I-V Characteristics and Usage as a RF Switch

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1 Aim

To find the forward voltage, reverse saturation current and ideality factor, the reverse recovery time of the given PIN diode at various frequencies and compare it with a regular PN diode and to show its working as an RF switch

2 Prelab Simulations

2.1 NGSPICE Code for IV Characteristics

```
*IV Characteristics of PIN Diode
.include rn142.txt

vs 1 0 dc 0

vy 2 3 dc 0
da 1 2 DRN142S
ra 3 0 100

.dc vs 0.001 5 0.01
.control

run
plot i(vy) vs {v(1) - v(2)}
plot ln(i(vy)) vs {v(1) - v(2)}
.endc
.endn
```

2.2 NGSPICE Code for Reverse Recovery Time

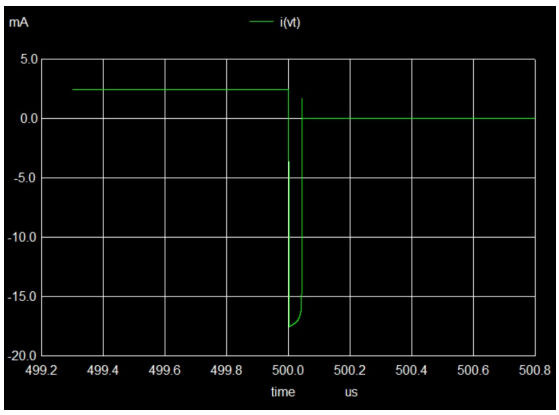
```
*Reverse Recovery Current
.include rn142.txt

*square wave sources - comment/uncomment using *
v1k 1 0 pulse(-1 1 0 1ns 1ns 0.5ms 1ms 0)
*v10k 1 0 pulse(-1 1 0 1ns 1ns 0.05ms 0.1ms 0)
*v100k 1 0 pulse(-1 1 0 1ns 1ns 0.005ms 0.01ms 0)

d1 1 4 DRN142S
vt 4 5 0 dc
ra 5 0 100

.tran 0.3ns 285.2us 284.8us
.control

run
plot i(vt)
.endc
.end
```

2.3 NGSPICE Code for RF Switch

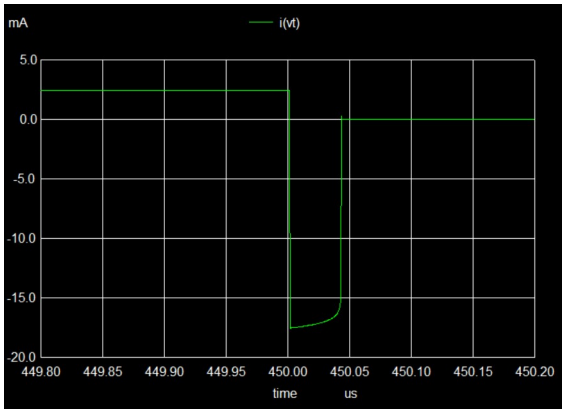
```
*RF Switch
.include rn142.txt

d1 1 7 DRN142S
vdiode 7 2 dc 0
c1 2 3 100n
r1 2 0 500
r2 1 4 500
voutput 5 6 dc 0
r3 6 0 50
c2 5 1 100n
vbias 4 0 dc -5
vin 3 0 sin(0 3 10MEG 0 0 0)
.tran 0.1ns 2us 1us
.control
run
plot v(5)
plot i(voutput) i(vdiode)
.endc
.end
```

2.4 Simulation Results

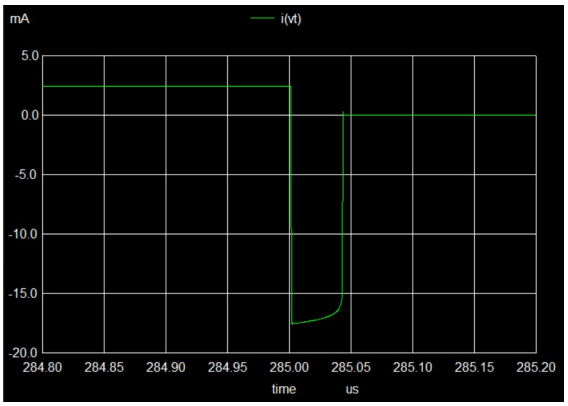
Ideality Factor	1.7573
5mA Cut In Voltage	0.794 V
Reverse Saturation Current	-130 pA
Reverse Response Time @ 1kHz	43 ns
Reverse Response Time @ 10kHz	43 ns
Reverse Response Time @ 100kHz	43 ns



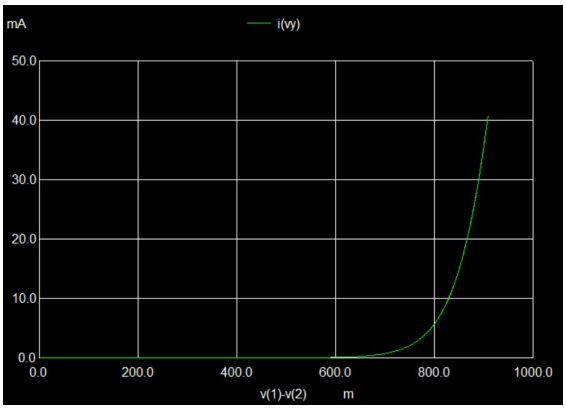
Reverse Response Time Waveform at 1kHz



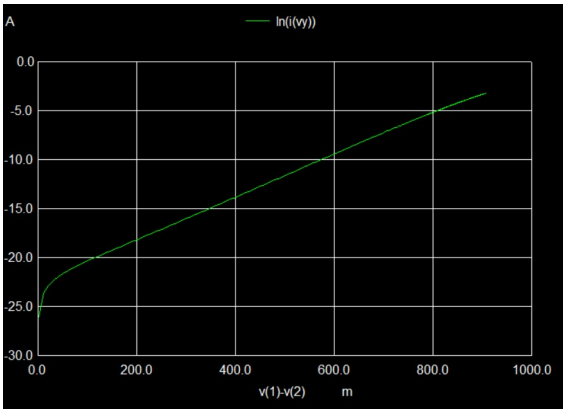
Reverse Response Time Waveform at 1kHz



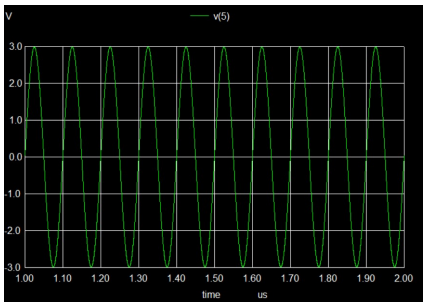
Reverse Response Time Waveform at 100kHz



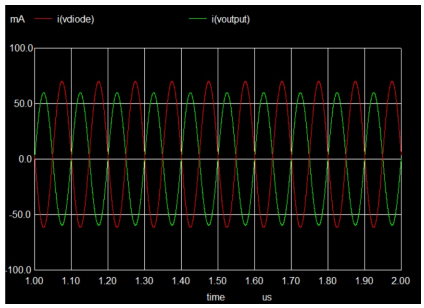
Simulated IV Characteristics for PIN Diode



Simulated log(I) vs V Characteristics for PIN Diode

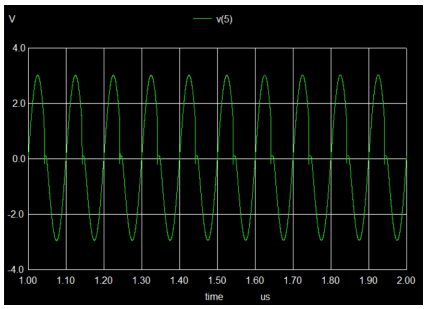


(a) Voltage Waveform

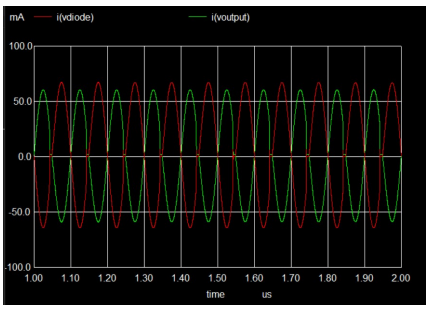


(b) Current Waveform

Figure 1: Behaviour of PIN based RF Switch at $V_{bias} = 5$V

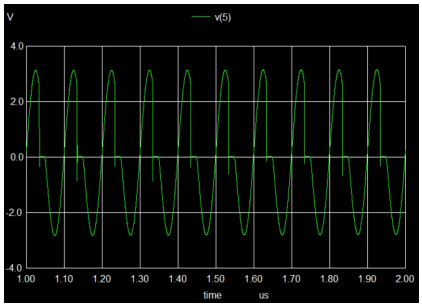


(a) Voltage Waveform

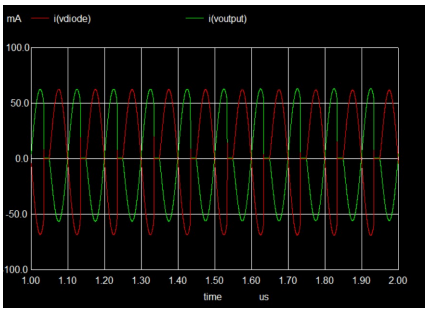


(b) Current Waveform

Figure 2: Behaviour of PIN based RF Switch at $V_{bias} = 3$V

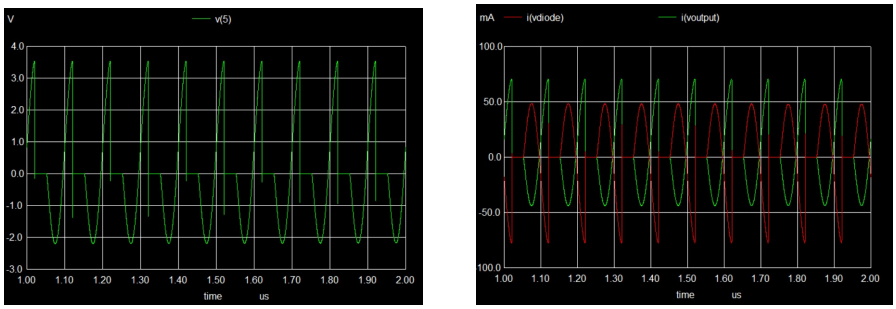


(a) Voltage Waveform



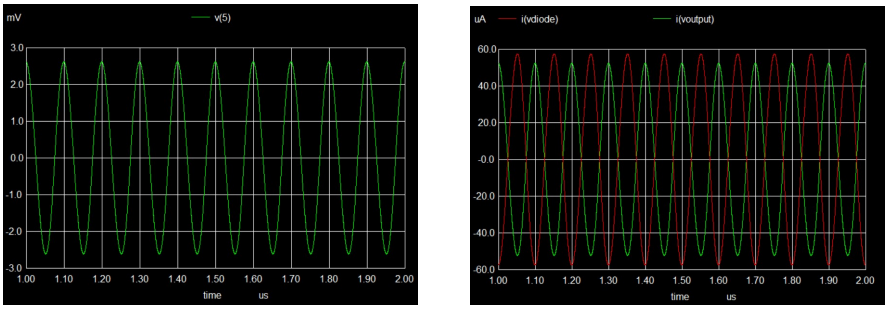
(b) Current Waveform

Figure 3: Behaviour of PIN based RF Switch at $V_{bias} = 1$V



(a) Voltage Waveform (b) Current Waveform

Figure 4: Behaviour of PIN based RF Switch at V_{bias} = 0V

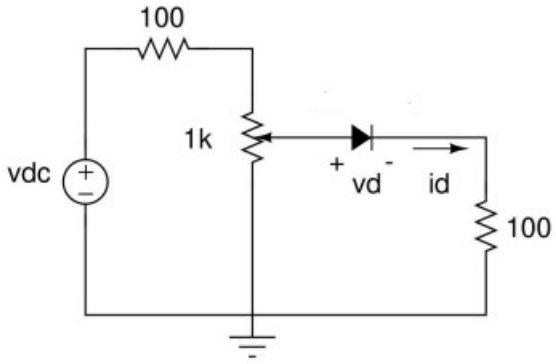


(a) Voltage Waveform (b) Current Waveform

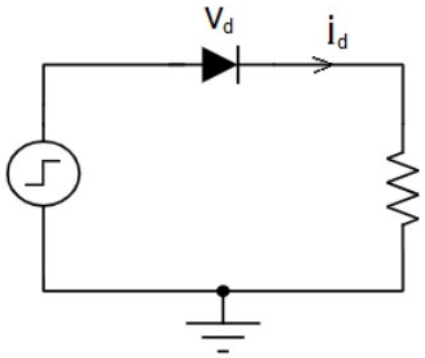
Figure 5: Behaviour of PIN based RF Switch at V_{bias} = -5V

3 Design

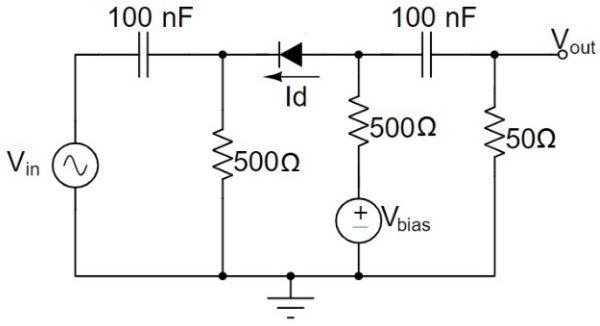
3.1 Circuit Diagrams



Circuit To Obtain IV Characteristics



Circuit for Reverse Recovery Time



Circuit for PIN Diode RF Switch Behaviour

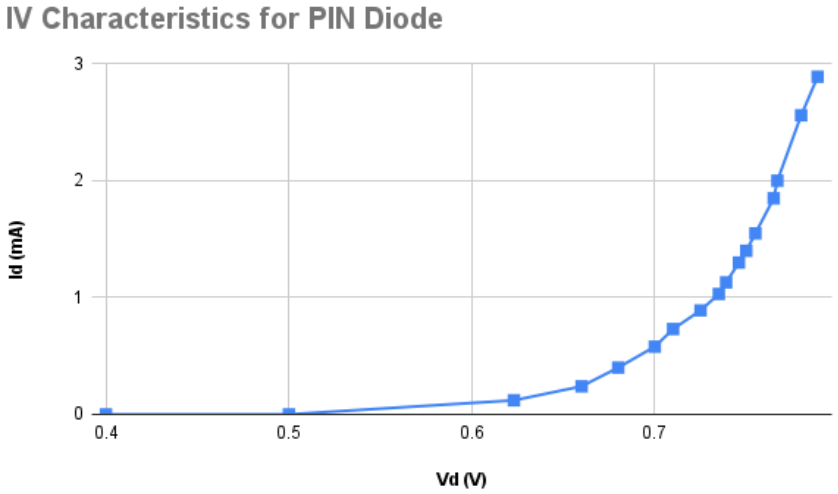
4 Observations

4.1 I-V Characteristics

The I-V characteristics were plotted for the PIN diode by varying the current and voltage by adjusting a 1k potentiometer and taking the following readings

Voltage V_D (V)	**Current I_D (mA)**
0.4	0
0.5	0
0.623	0.12
0.66	0.24
0.68	0.4
0.7	0.58
0.71	0.73
0.725	0.89
0.735	1.03
0.739	1.13
0.746	1.3
0.75	1.4
0.755	1.55
0.765	1.85
0.767	2
0.78	2.56
0.789	2.89

Obtained I-V Readings



Plot Obtained from Readings

4.2 Reverse Recovery Time

Frequency	PN Junction	PIN Diode
10kHz	4 us	250 ns
100kHz	1.5 us	230 ns
1MHz	400 ns	160 ns
10MHz	50 ns	46 ns

Observed Values of Reverse Recovery Time

Thus we notice that at 10 MHz, the PIN diode has better potential of passing major part of i/p signal than PN diode due to lesser RRT

4.3 Characterizing PIN Diode as an RF Switch

V_{bias} (V)	I_D (mA)	V_D (V)
5	4.18	0.8
3	2.27	0.767
1	0.7	0.325
0	0.35	-0.27
-5	0	-5.4

Readings for PIN Diode for varying DC biases

V_{bias} (V)	I_D (mA)	V_D (V)
5	4.32	0.65
3	2.37	0.62
1	0.45	0.55
0	0.03	0.1
-5	0	-5.48

Readings for PN Junction Diode for varying DC biases

5 Post Lab Simulation

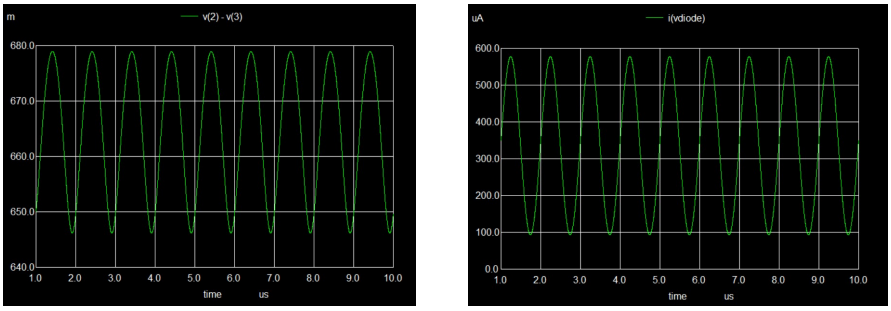
5.1 NGSPICE Code

```
*Measuring Dynamic Resistance
.include rn142.txt

vin 1 0 sin(0 0.25 1MEG 0 0 0)
vdc 2 1 dc 1
da 2 3 DRN142S
vdiode 3 4 dc 0
ra 4 0 1k

.tran 1ns 10us 1us
.control

run
plot v(2) - v(3)
plot i(vdiode)
let vd = {v(2) - v(3)}
meas tran vpp pp vd from=1us to=10us
meas tran ipp pp i(vdiode) from=1us to=10us
let dr = {vpp/ipp}
print dr
.endc
.end
```

5.2 Simulation Results

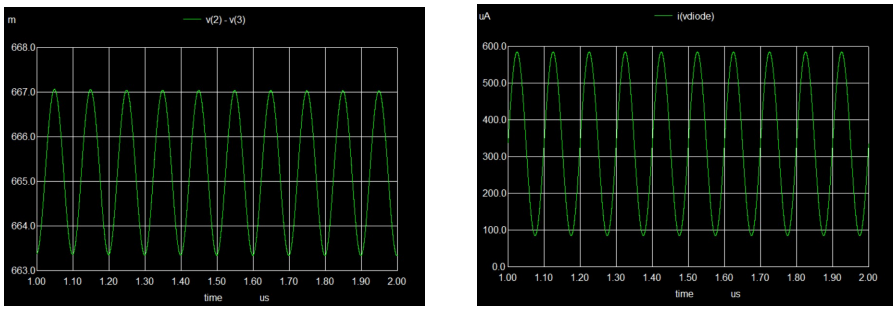
Parameter	**1MHz**	**10MHz**
Diode Voltage (p2p) in mV	32.77	3.725
Diode Current (p2p) in mA	0.4841	0.4997
Dynamic Resistance (Ω)	67.69	7.455

Parameters obtained via Simulation



(a) Voltage Waveform (b) Current Waveform

Figure 6: Plots obtained for 1MHz Frequency



(a) Voltage Waveform (b) Current Waveform

Figure 7: Plots obtained for 10MHz Frequency

6 Experiment Completion Status

The experiment was completed in the lab hours and the values and plots obtained for the various diodes, the simulation outputs were shown to the TA and were verified. The `.xlsx` containing all the readings and plots after verification from the TA were uploaded on Moodle during the lab hours