EE 236: Experiment 2
PIN Diode I-V Characteristics and Usage as an 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
.end
```

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

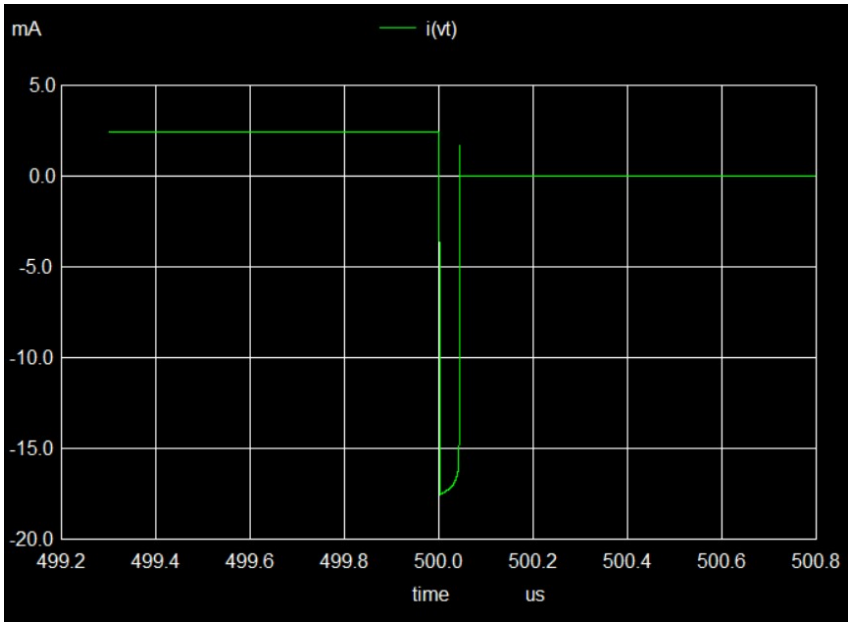

Figure 1: Reverse Response Time Waveform at 1kHz

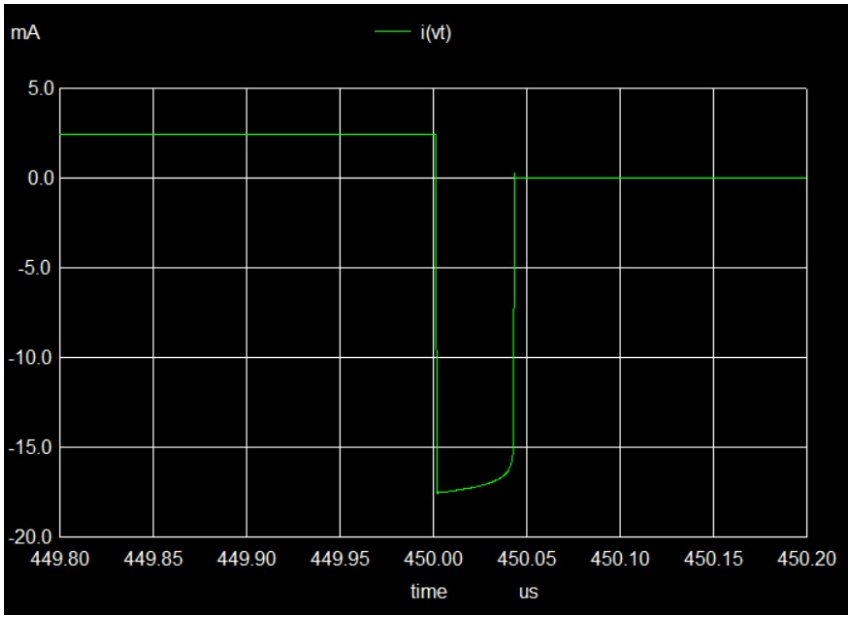

Figure 2: Reverse Response Time Waveform at 10kHz

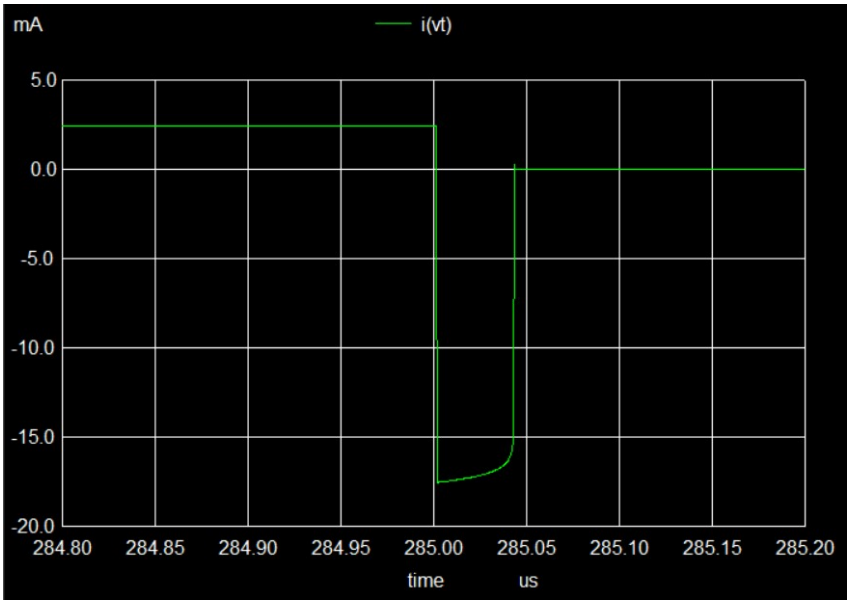

Figure 3: Reverse Response Time Waveform at 100kHz

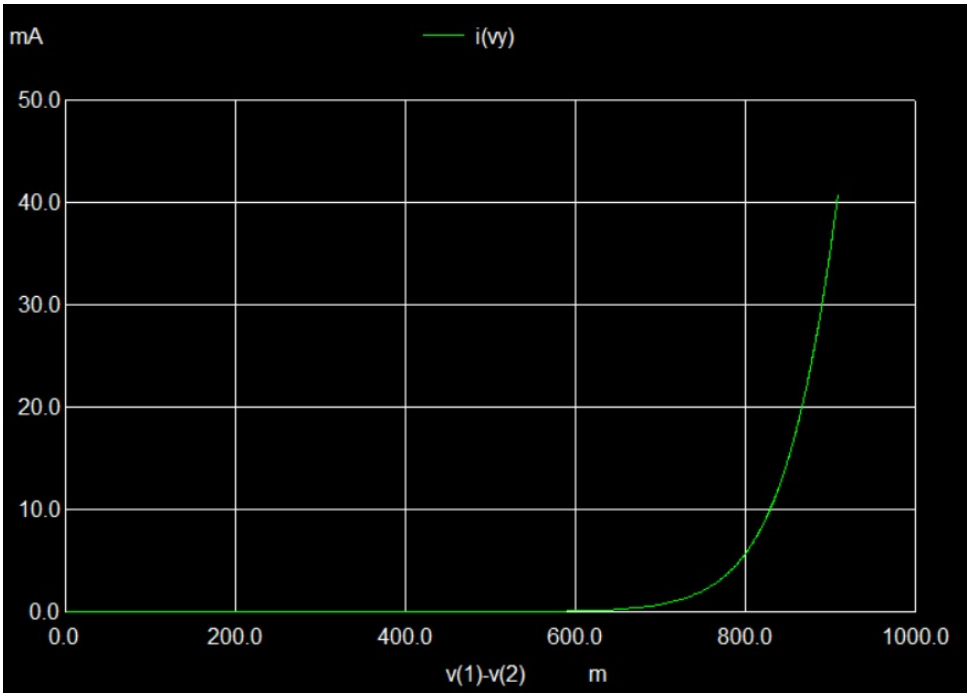

Figure 4: Simulated IV Characteristics for PIN Diode

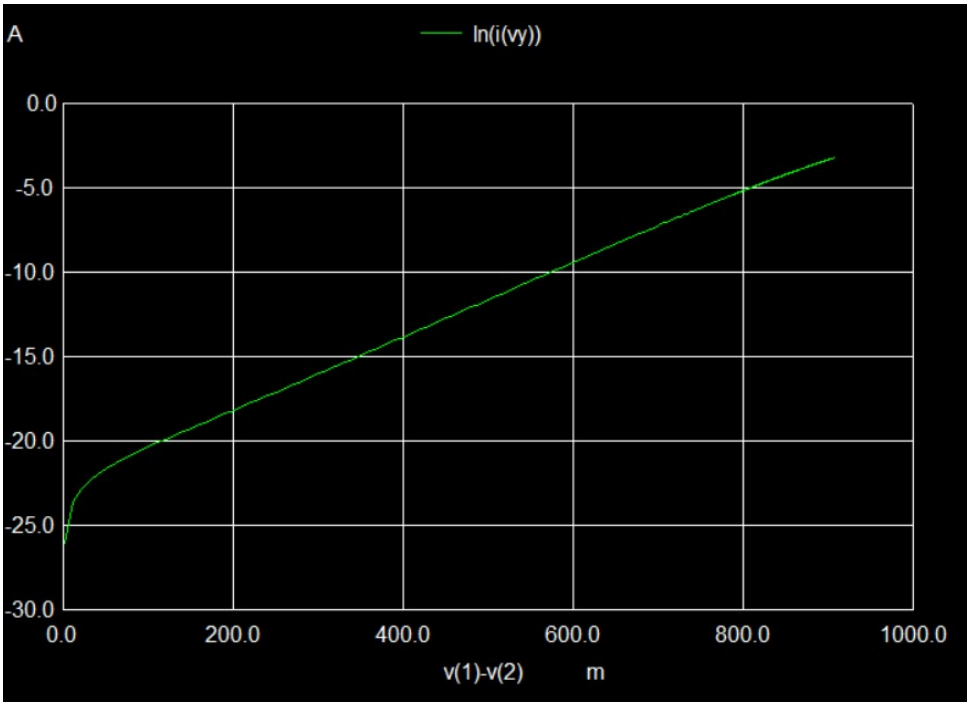

Figure 5: Simulated log(I) vs V Characteristics for PIN Diode

3 Behaviour of PIN Diode as an RF Switch

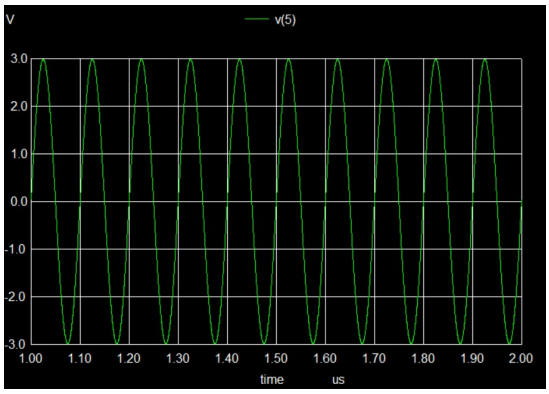

Figure 6: (a) Voltage Waveform

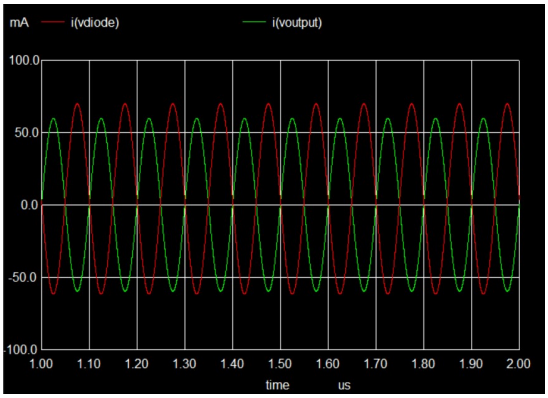

Figure 7: (b) Current Waveform

Figure 8: Behaviour of PIN based RF Switch at $V_{bias} = 5V$

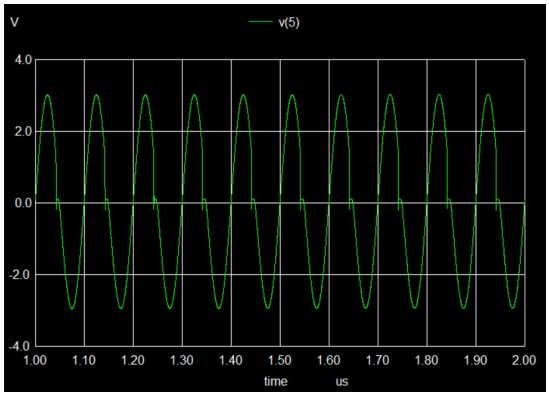

Figure 9: (a) Voltage Waveform

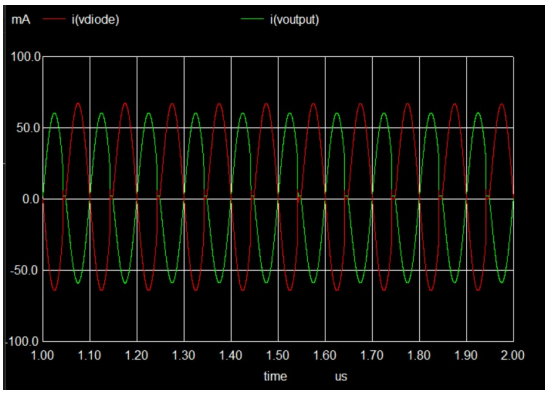

Figure 10: (b) Current Waveform

Figure 11: Behaviour of PIN based RF Switch at $V_{bias} = 3V$

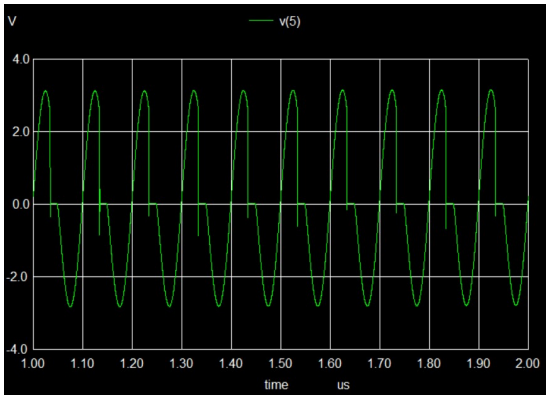

Figure 12: (a) Voltage Waveform

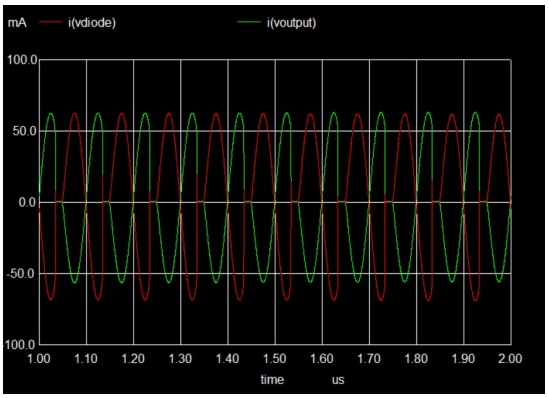

Figure 13: (b) Current Waveform

Figure 14: Behaviour of PIN based RF Switch at $V_{bias} = 1V$

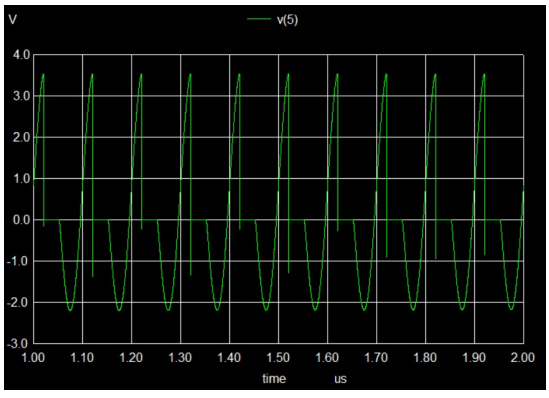

Figure 15: (a) Voltage Waveform

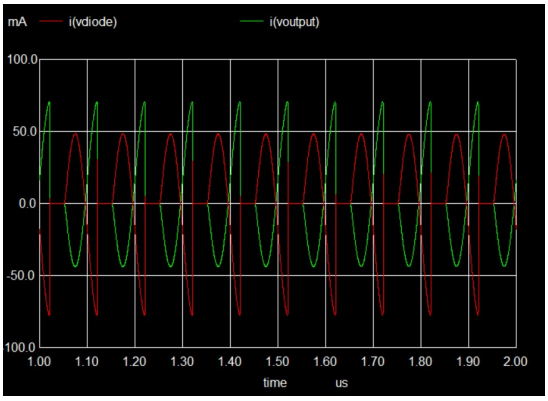

Figure 16: (b) Current Waveform

Figure 17: Behaviour of PIN based RF Switch at $V_{bias} = 0V$

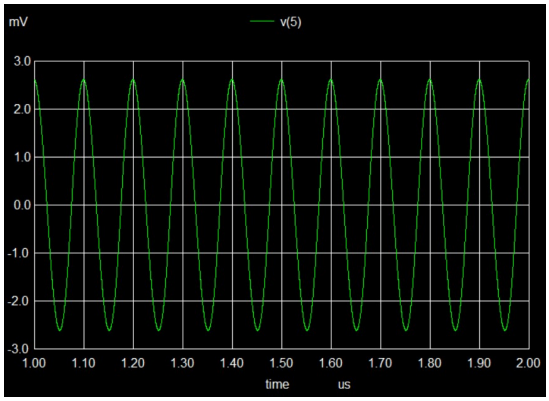

Figure 18: (a) Voltage Waveform

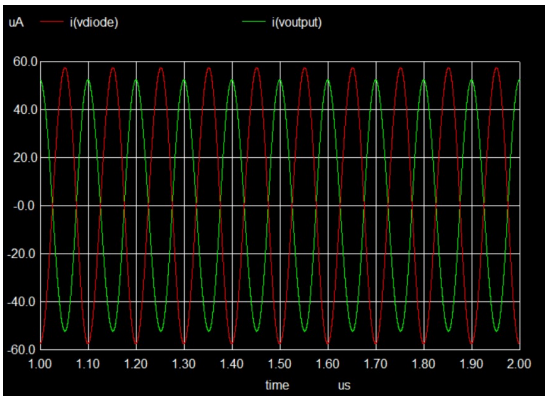

Figure 19: (b) Current Waveform

Figure 20: Behaviour of PIN based RF Switch at $V_{bias} = -5V$

4 Design

4.1 Circuit Diagrams

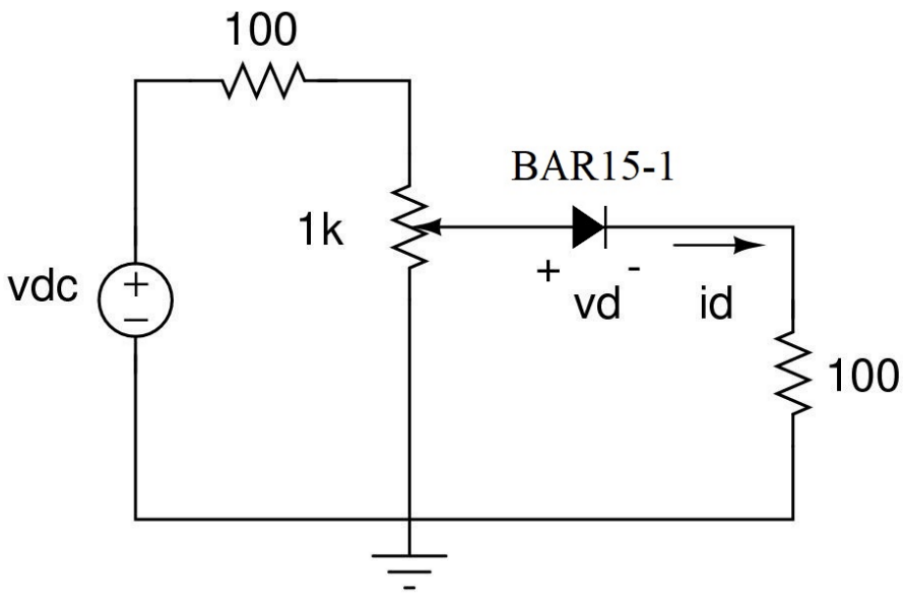

Figure 21: Circuit To Obtain IV Characteristics

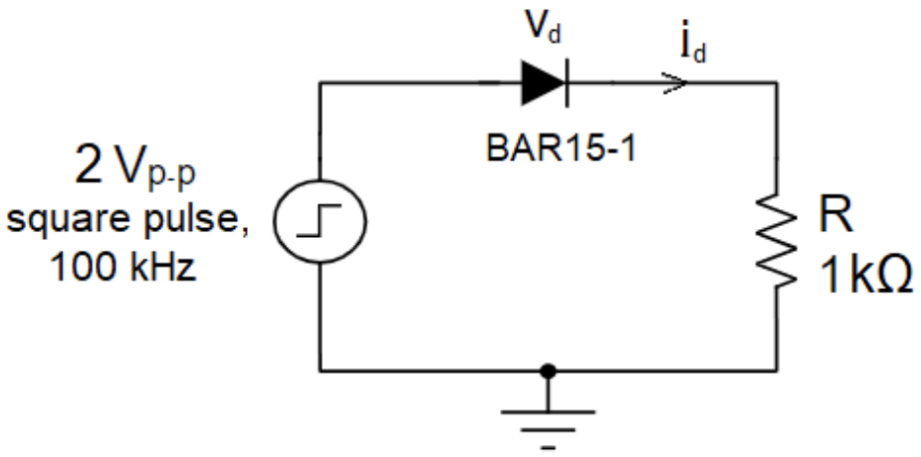

Figure 22: Circuit for Reverse Recovery Time

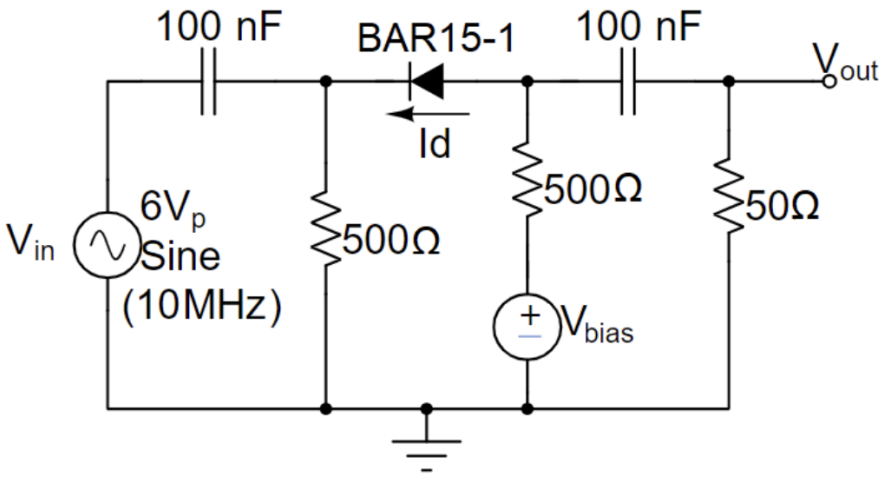

Figure 23: Circuit for PIN Diode RF Switch Behaviour

5 Observations

5.1 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:

V_D (V)	I_D (mA)	$\ln(I_D)$
0	0	0
0.46	0.0002	-4.698970004
0.52	0.0012	-3.920818754
0.59	0.0048	-3.318758763
0.64	0.0127	-2.896196279
0.67	0.025	-2.602059991
0.72	0.056	-2.251811973
0.73	0.076	-2.119186408
0.76	0.1266	-1.897566294
0.78	0.185	-1.732828272
0.79	0.404	-1.393618635
0.84	0.82	-1.086186148
0.86	1.32	-0.879426069
0.9	2.86	-0.543633967
0.92	3.52	-0.453457337

Table 1: Obtained I-V Readings

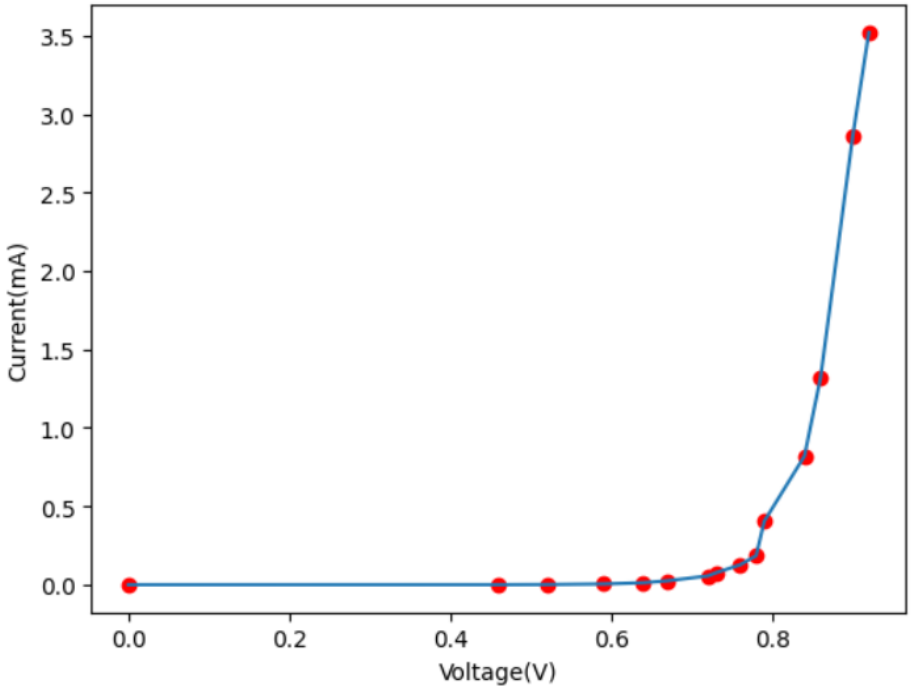

Figure 24: Plot Obtained from Readings - I-V Characteristics

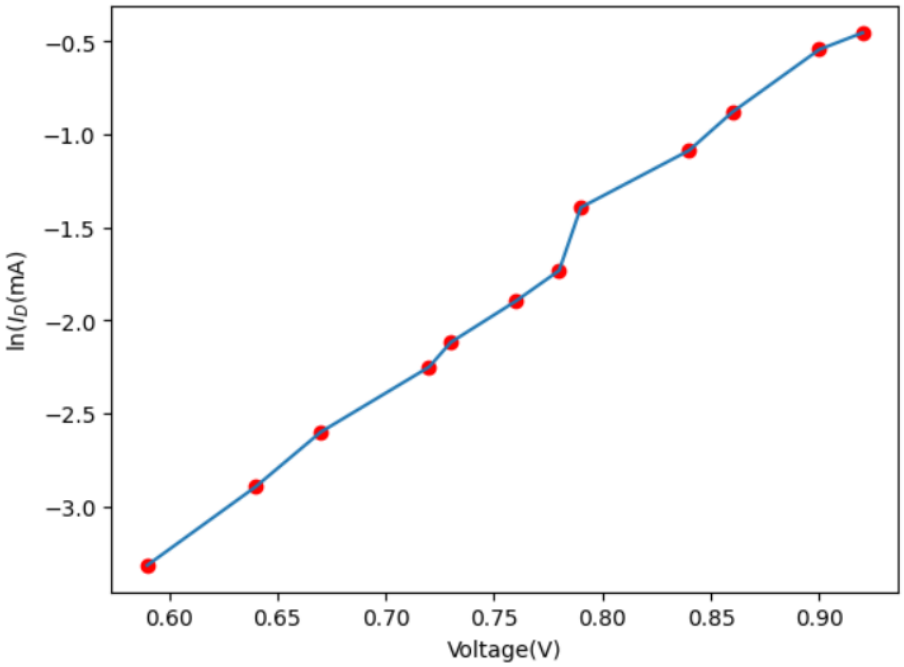

Figure 25: Plot Obtained from Readings - Log(I)-V Characteristics

5.2 Reverse Recovery Time

Frequency (kHz)	Recovery Time (PN)	Recovery Time (PIN)
10	5.52 μs	4.02 μs
100	3.14 μs	2.92 μs
1000	450 ns	343 ns
3000	170 ns	161 ns

Table 2: Observed Values of Reverse Recovery Time for PN and PIN Diodes

Thus, we notice that, at 3 MHz, the **PIN diode** has the potential of passing a major portion of the input signal to the output compared to the PN diode.
This is because the PIN diode has a **faster recovery time** (in the range of nanoseconds) due to the **intrinsic layer**, which allows it to handle higher frequencies more efficiently. On the other hand, the PN diode has a slower recovery time, making it less effective at passing high-frequency signals like those at 3 MHz.

5.3 Characterizing PIN Diode as an RF Switch

Vbias (V)	ID (mA)	VD (V)
5	4.25	0.8
3	2.24	0.767
1	0.7	0.325
0	0.35	-0.27
-5	0	-5.4

Table 3: Readings for PIN Diode for varying DC biases

Vbias (V)	ID (mA)	VD (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

Table 4: Readings for PN Diode for varying DC biases

6 Conclusion

The forward voltage, reverse saturation current, and ideality factor were determined. Reverse recovery times were measured at different frequencies for comparison between the PIN and PN junction diodes. The PIN diode's performance as an RF switch was successfully demonstrated.

7 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