EE236: Lab 1
PIN Diode I-V Characteristics & usage as RC Switch

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August 29, 2022

1 Aim of the experiment

1. To find forward voltage, reverse saturation current and ideality factor of the given PIN diode (Infineon BAR 15-1) and compare with normal PN junction Diode (1N4007).

2. To find reverse recovery time of the given PIN diode at various frequencies and compare with the reverse recovery time of normal PN junction Diode.

3. To observe how the PIN diode works as an RF switch at different DC bias voltages.

4. To find the relation between bias current and RF resistance (dynamic resistance) of the PIN diode at different frequencies.

2 Design & Working

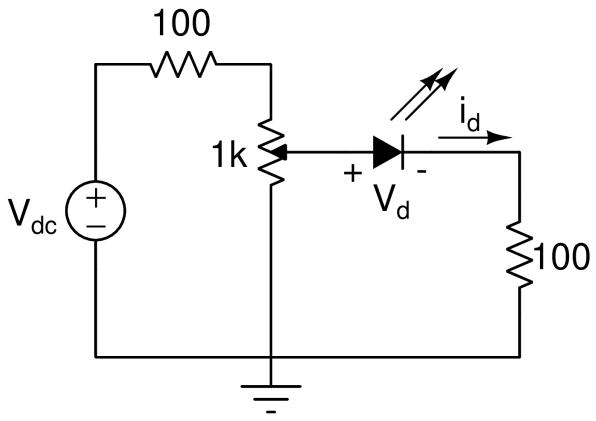

Fig. Circuit to measure I/V Characteristics of a semiconductor diode

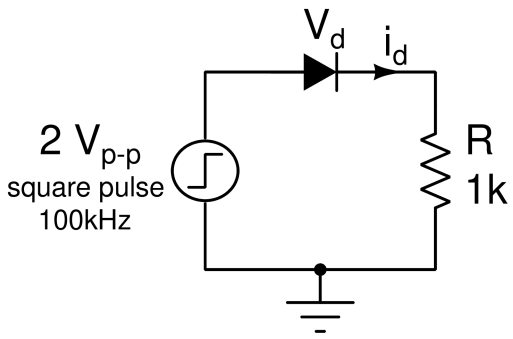

Fig. Circuit to measure Reverse Recovery Time

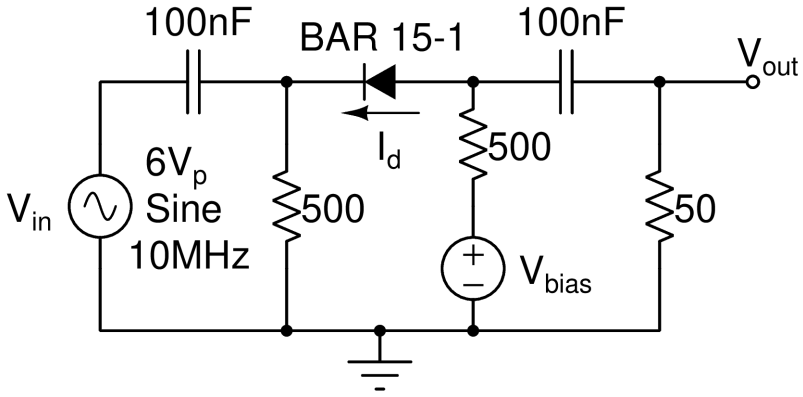

Fig. Circuit to characterize PIN diode as RF switch

3 Simulation

3.1 Code Snippet

3.1.1 I-V Characteristics

```
Diode I-V Characteristics

.include rn142.txt
Vs 1 0 dc 20
D1 1 2 DRN142S
R1 2 12 100
V1 12 0 dc 0
.dc Vs 0.01 5 0.01
.control
run
set color0 = white
set color1 = black
set color2 = red
plot i(V1) vs v(1,2)
set color0 = white
set color1 = black
set color2 = red
meas dc cutin find v(1,2) when i(V1) = 1m
plot ln(i(V1)) vs v(1,2)
.endc
.end
```

3.1.2 Reverse Recovery Time

```
Reverse Recovery Time for RN142

.include rn142.txt
Vp 1 0 pulse(-1 1 0ns 1ns 1ns 1ms 2ms)
Vdummy 1 2 dc 0
Rd 2 3 100
D 3 0 DRN142S
.tran 10ns 3.0001ms 2.99999ms
.control
```

```
run
plot i(Vdummy)
plot v(3)
meas tran tstart MIN_AT i(Vdummy)
meas tran tstop MAX_AT i(Vdummy) from=tstart
print tstop - tstart
.endc
.end
```

3.1.3 RF Switch

```
RF Switch Circuit

.include rn142.txt
Vin in 0 sin(0 6 10Meg 0 0)
C1 in 1 100n
R1 1 0 500
D dummy1 1 DRN142S
Vdummy1 2 dummy1 dc 0 ac 0
R2 2 3 500
Vbias 3 0 dc 0
C2 2 out 100n
R3 out dummy2 50
Vdummy2 0 dummy2 dc 0 ac 0
.tran 0.1n 1u
.control
run
plot v(out) v(in)
plot i(Vdummy1) i(Vdummy2)
.endc
.end
```

3.2 Simulation Results

3.2.1 I-V Characteristics

Given below is the plot for I_D vs V_D waveform for the PIN diode obtained from the dc analysis of the circuit:

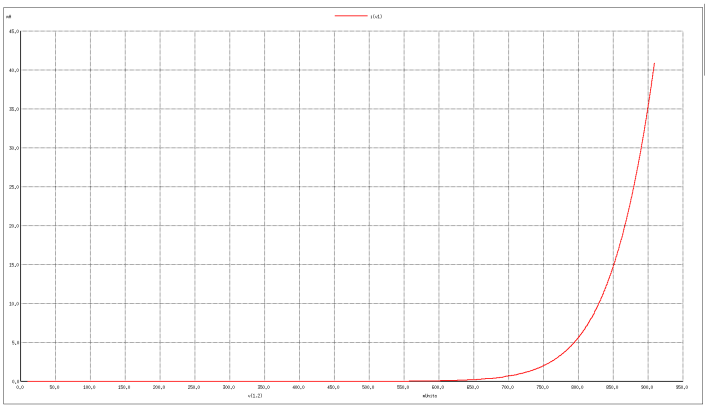

Fig. I-V Characteristics for the PIN Diode

Using the above plot, we find the cutin voltage to be $0.716V$ and the ideality factor to be 1.788

3.2.2 Reverse Recovery Time

Given below is the plot for I_D waveform for the PIN diode with a 1kHz input pulse, obtained from the transient analysis of the circuit:

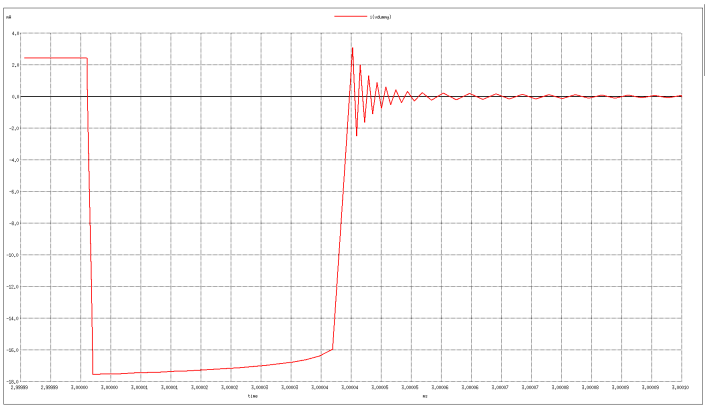

Fig. I_D plot for PIN Diode at 1kHz

Given below is the plot for I_D waveform for the PIN diode with a 10kHz input pulse, obtained from the transient analysis of the circuit:

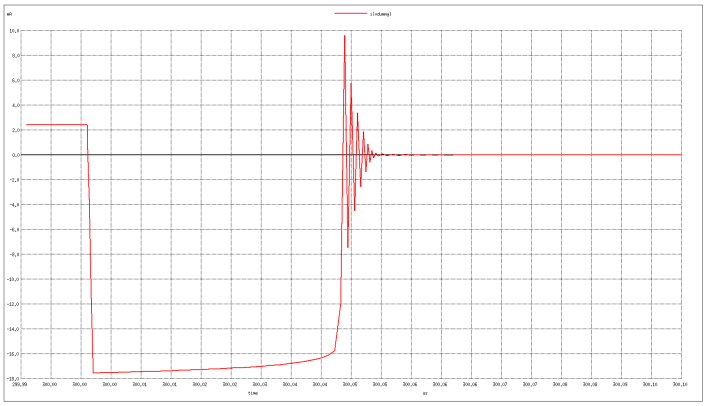

Fig. I_D plot for PIN Diode at 10kHz

Given below is the plot for I_D waveform for the PIN diode with a 100kHz input pulse, obtained from the transient analysis of the circuit:

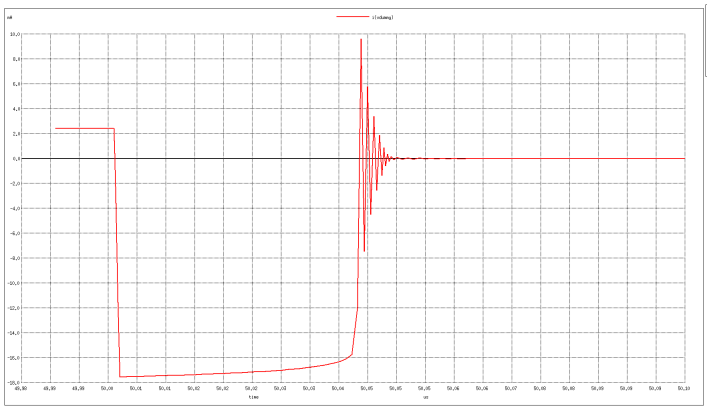

Fig. I_D plot for PIN Diode at 100kHz

Given below are the measured readings using the above simulations for RRT for the PIN diode at various frequencies:

Frequency	RRT of PIN
$1k$	$43ns$
$10k$	$41.9ns$
$100k$	$41.85ns$

3.2.3 RF Switch

Given below are the plots for output voltage, output current and diode current for the RF Switch circuit at $V_{bias} = -5V$

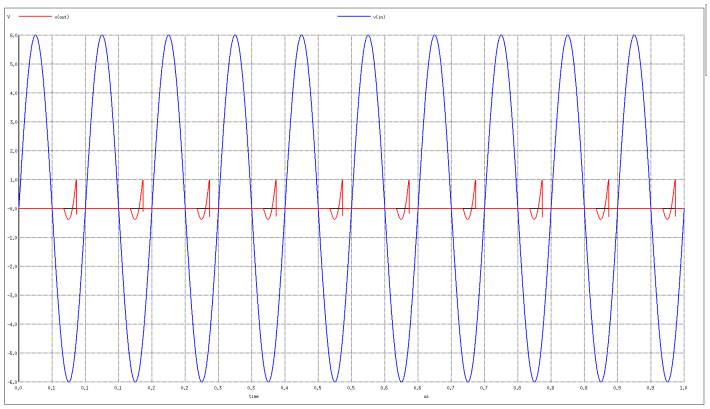

Fig. V_{out} and V_{in} plot for PIN Switch circuit at $V_{bias} = -5V$

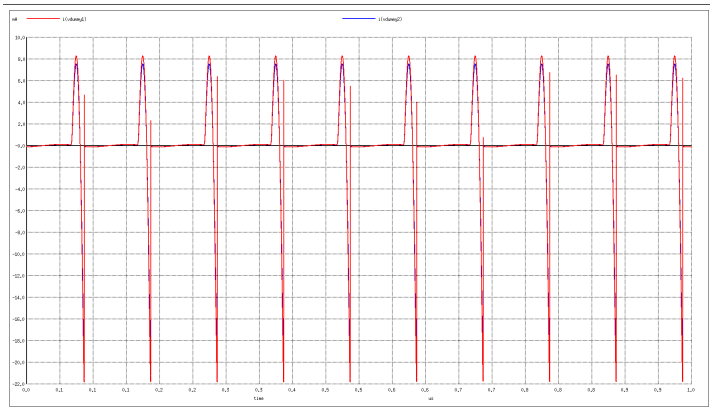

Fig. i_{out} and i_D plot for PIN Switch circuit at $V_{bias} = -5V$

Given below are the plots for output voltage, output current and diode current for the RF Switch circuit at $V_{bias} = 0V$

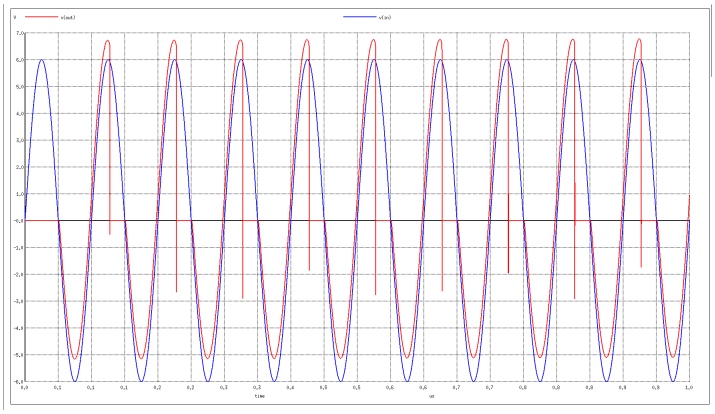

Fig. V_{out} and V_{in} plot for PIN Switch circuit at $V_{bias} = 0V$

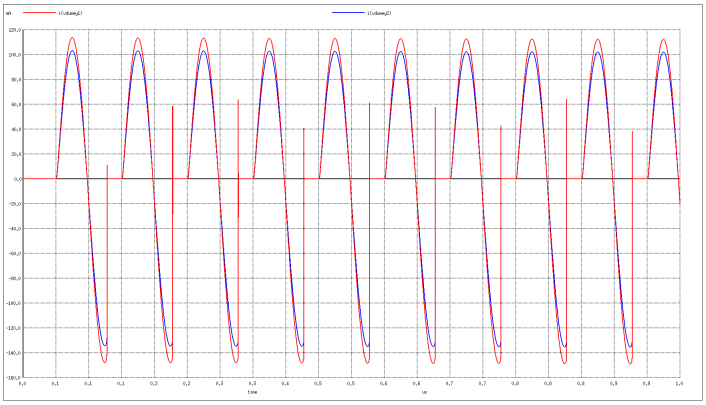

Fig. i_{out} and i_D plot for PIN Switch circuit at $V_{bias} = 0V$

Given below are the plots for output voltage, output current and diode current for the RF Switch circuit at $V_{bias} = 1V$

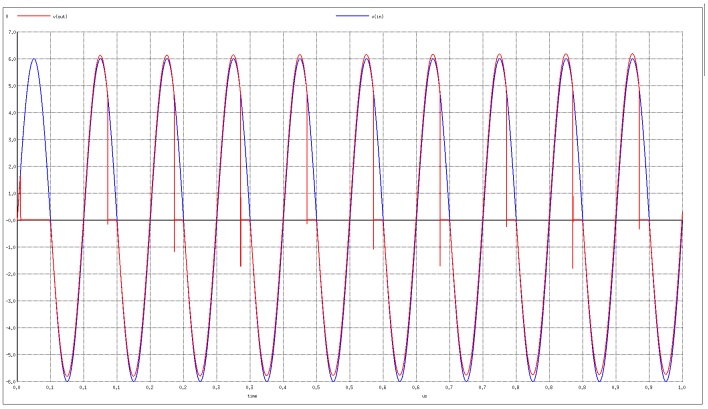

Fig. V_{out} and V_{in} plot for PIN Switch circuit at $V_{bias} = 1V$

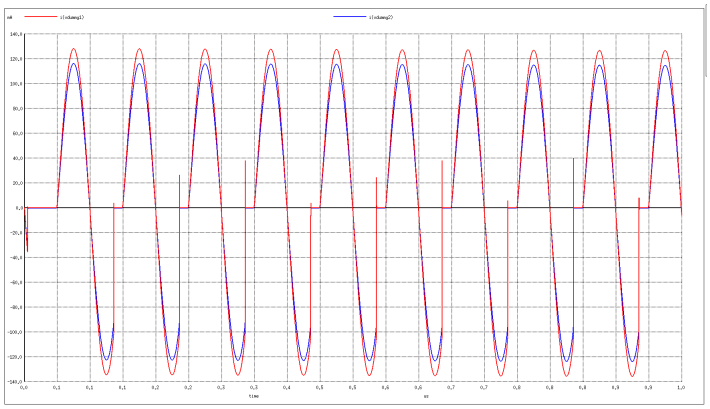

Fig. i_{out} and i_D plot for PIN Switch circuit at $V_{bias} = 1V$

Given below are the plots for output voltage, output current and diode current for the RF Switch circuit at $V_{bias} = 3V$

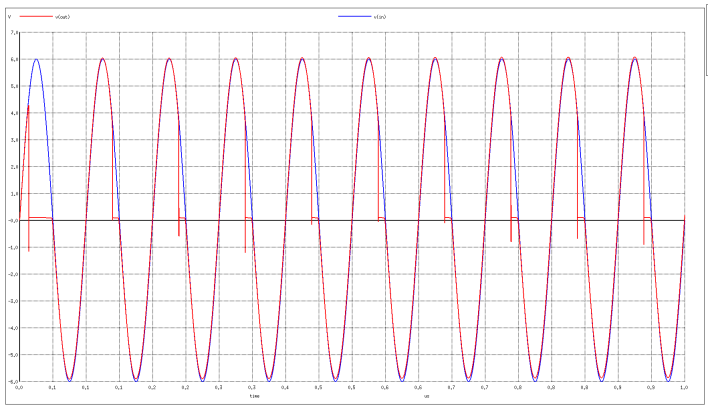

Fig. V_{out} and V_{in} plot for PIN Switch circuit at $V_{bias} = 3V$

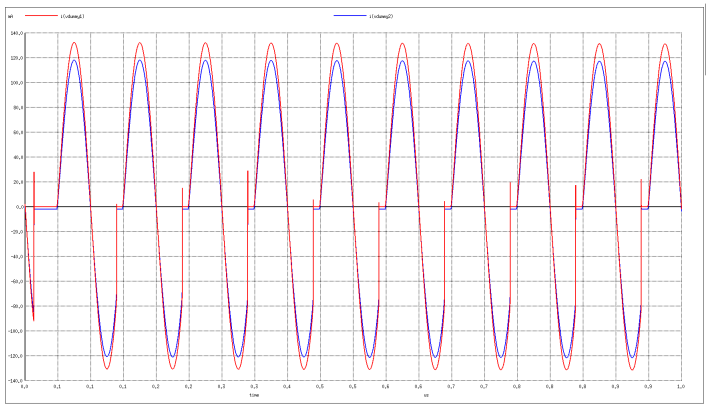

Fig. i_{out} and i_D plot for PIN Switch circuit at $V_{bias} = 3V$

Given below are the plots for output voltage, output current and diode current for the RF Switch circuit at $V_{bias} = 5V$

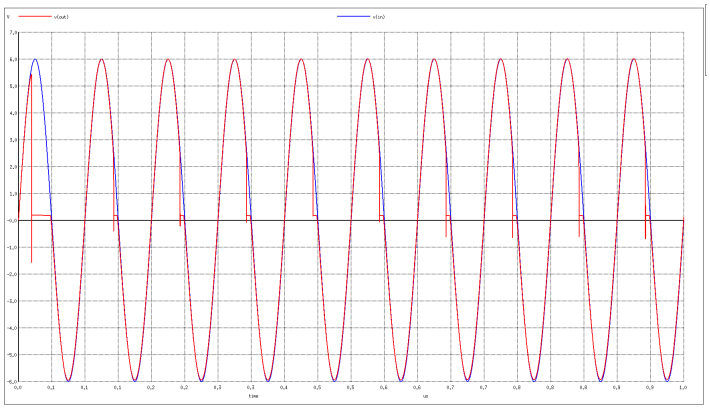

Fig. V_{out} and V_{in} plot for PIN Switch circuit at $V_{bias} = 5V$

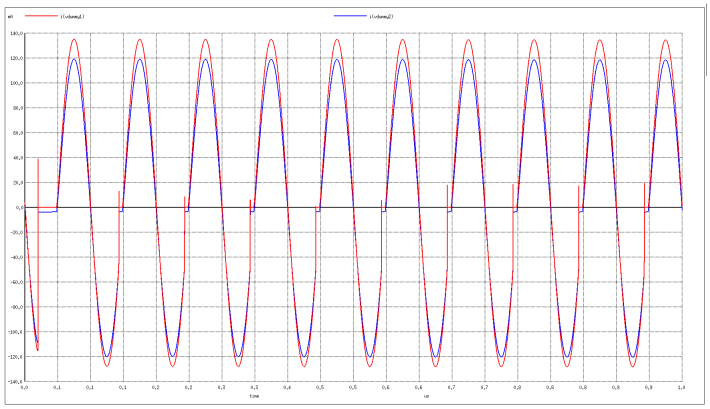

Fig. i_{out} and i_D plot for PIN Switch circuit at $V_{bias} = 5V$

4 Experimental Results

4.1 I-V Characteristics

Given below are my readings for I_D and V_D for the PIN diode:

V_D (in mV)	I_D (in μA)
0	0
94	76
208	77
306	116
398	128
502	167
604	208
709	278
805	378
845	447
905	683
953	890
1009	4830

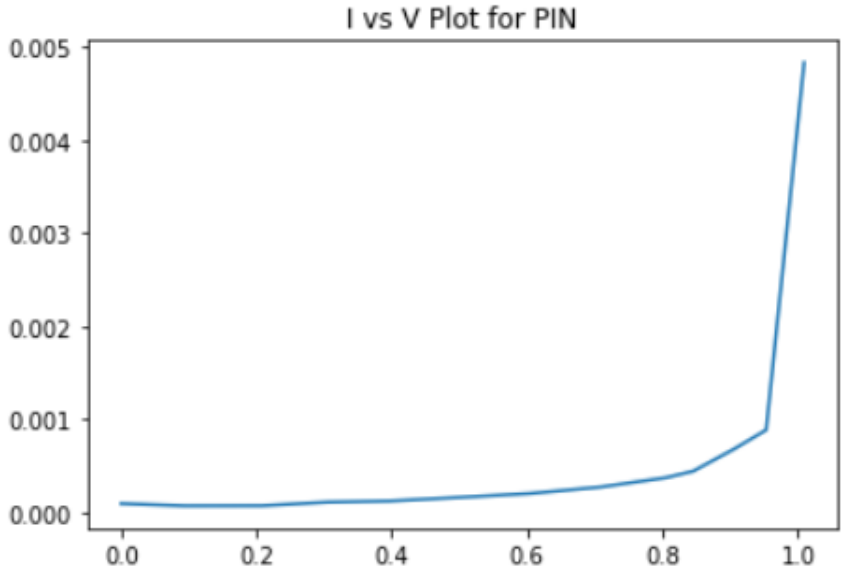

Fig. I-V Characteristics for the PIN diode

4.2 Reverse Recovery Time

Given below are the observed readings for RRT for the PIN diode at various frequencies:

Frequency	RRT of PIN	RRT of PN
$10k$	$190ns$	$1.8\mu s$
$100k$	$160ns$	$0.8\mu s$
$1M$	$150ns$	$100ns$
$10M$	-	-

4.2.1 RF Switch

Given below are the observed readings for output voltage, diode voltage and diode current for the PIN Switch circuit:

V_{bias}	V_{p-p}^{out}	I_D	V_D
$-5V$	$88mV$	$0.01\mu A$	$-5.09V$
$0V$	$188mV$	$74\mu A$	$5.7mV$
$1V$	$344mV$	$0.59mA$	$0.397V$
$3V$	$464mV$	$2.3mA$	$0.777V$
$5V$	$512mV$	$4.25mA$	$0.813V$

5 Simulation Exercise

In order to find the relation between RF resistance and bias current of the PIN diode at different frequencies, we can use the following circuit:

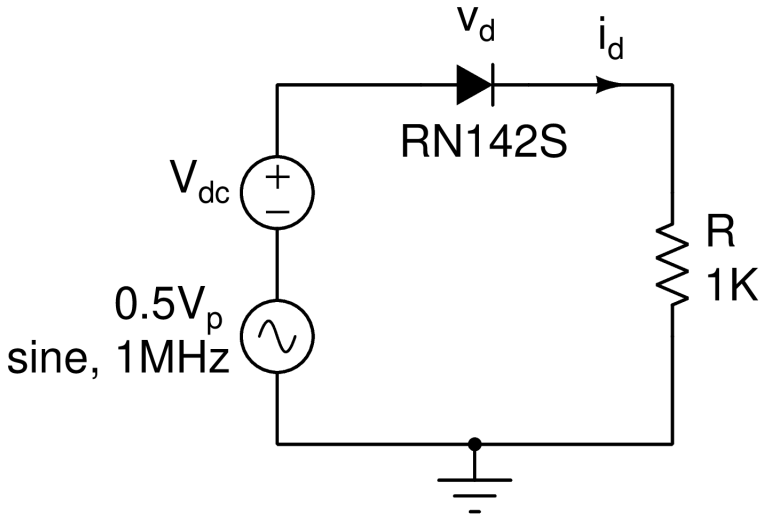

Fig. Circuit to find dynamic resistance

5.1 Code Snippet

```
Dynamic Resistance

.include rn142.txt
Vrf 1 0 sin(0 125m 1Meg 0 0)
Vdc 2 1 dc 1
r 2 dummy 1k
vdummy dummy 3 dc 0 ac 0
d 3 0 DRN142S
.tran 0.1n 5u 0.1n
.control
run
meas tran vpp PP v(3)
meas tran ipp PP i(vdummy)
.endc
.end
```

5.2 Simulation Results

Dynamic Resistance is given by:

$$R = \frac{V_{p-p}^{D}}{i_{p-p}^{D}}$$

Given below are the readings for V_{p-p}^{D} and i_{p-p}^{D} obtained using the above simulation at 1MHz and 10MHz:

Frequency	V_{p-p}^{D}	i_{p-p}^{D}	R_D
1MHz	$1.592 \times 10^{-2} V$	$2.421 \times 10^{-4} A$	65.758Ω
10MHz	$1.847 \times 10^{-3} V$	$2.499 \times 10^{-4} A$	7.391Ω