I-V Characteristics of a diode

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1 Aim

- To study I-V characteristics of a p-n junction diode (Si/ Ge).
- Also, to Find: Dynamic and Static Resistance of the Si Diode used.

2 Apparatus Required

p-n junction diode, voltmeter, micro/mili-ammeter, resistance, DC voltage source

3 Diagram

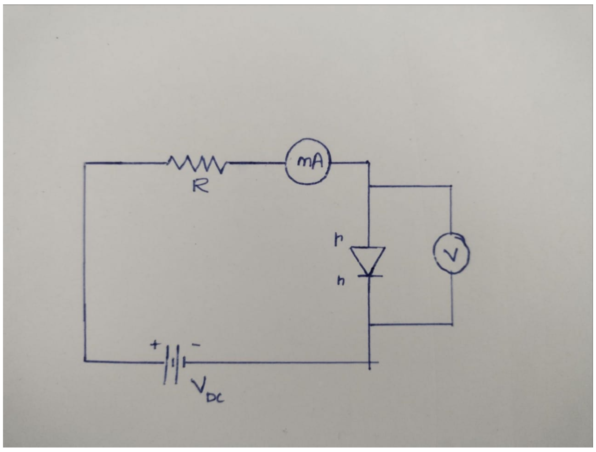

Figure 1: forward biased

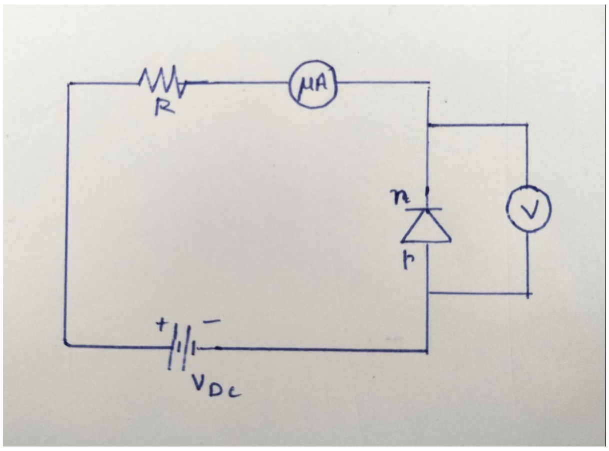

Figure 2: reverse biased

4 Formula Used

4.1 Diode Equation

$$I_f = I_s \left(\exp\left(\frac{V_f}{\eta \left(\frac{kT}{q} \right)} \right) - 1 \right) \tag{1}$$

where
$I_s \equiv$ reverse saturation current, $I_f \equiv$ forward current, $V_f \equiv$ forward voltage,
$V_T = \frac{kT}{q} \equiv$ thermal voltage, $k \equiv$ Boltzmann constant, $T \equiv$ absolute temperature,
$q \equiv$ electronic charge

4.2 Static Resistance

$$r_s = \frac{V_{dQ}}{I_{dQ}} \tag{2}$$

i.e. it is defined as the ratio of the voltage across the diode to the current flowing through the diode.

In reverse bias, $r_s >>> 1$.

4.3 Dynamic Resistance

$$r_d = \frac{\Delta V}{\Delta I} \tag{3}$$

i.e. it is defined as the ration of the change in voltage across the diode for some corresponding change in the current flowing through the diode. Used, generally, in AC analysis.

5 Theory

5.1 Forward Bias

Poistive terminal of the battery is connected with the p side, and the negative terminal is connected with the n side of the diode. Due to the applied voltage (and the drift current), the width of the depletion region starts decreasing. Hence, a forward current starts flowing through the diode.

In an ideal case, the diode acts as a closed switch.

For Silicon, the cut-in/knee voltage is 0.6V.
For Germanium, the cut-in/knee voltage is 0.3V.

5.2 Reverse Bias

Poistive terminal of the battery is connected with the n side, and the negative terminal is connected with the p side of the diode. Due to this biasing, very little or no current flows through the diode until Zener/Avalanche breakdown occurs. This can also be explained by the increase in the width of the depletion region.

In an ideal case, the diode acts as an open switch.

6 Observations and Plots, and Static Resistances

6.1 Silicon Diode IN4001

- Forward Bias

  1. Resistance, R = 100Ω

S.No.	V_{dc}	$V_f(V)$	$I_f(mA)$	**Static Resistance (x$10^3\Omega$)**
01	0	0	0	N.A.
02	0.7	0.589	0.997	0.5907
03	0.8	0.593	1.99	0.2979
04	0.9	0.596	2.99	0.1993
05	1.0	0.599	3.99	0.1501
06	1.1	0.601	4.99	0.1204
07	1.2	0.603	5.98	0.1000
08	1.3	0.605	6.98	0.0866
09	1.4	0.607	7.98	0.0760
10	1.5	0.609	8.97	0.0678
11	1.6	0.611	9.97	0.0612
12	1.7	0.612	11.0	0.0556
13	1.8	0.614	12.0	0.0511
14	1.9	0.615	13.0	0.0473
15	2.0	0.617	14.0	0.0440
16	2.2	0.619	16.0	0.0386
17	2.4	0.621	17.9	0.0349
18	2.6	0.624	19.9	0.03134
19	2.8	0.625	21.9	0.0285
20	3.0	0.627	23.9	0.026
21	3.2	0.629	25.9	0.0242
22	3.4	0.630	27.9	0.0225
23	3.6	0.632	29.9	0.0211
24	3.8	0.633	31.9	0.0198
25	4.0	0.635	33.9	0.0187
26	4.2	0.636	35.9	0.0177
27	4.4	0.637	37.9	0.0168
28	4.6	0.638	39.9	0.0159
29	4.8	0.639	41.9	0.0152
30	5.0	0.641	43.9	0.014

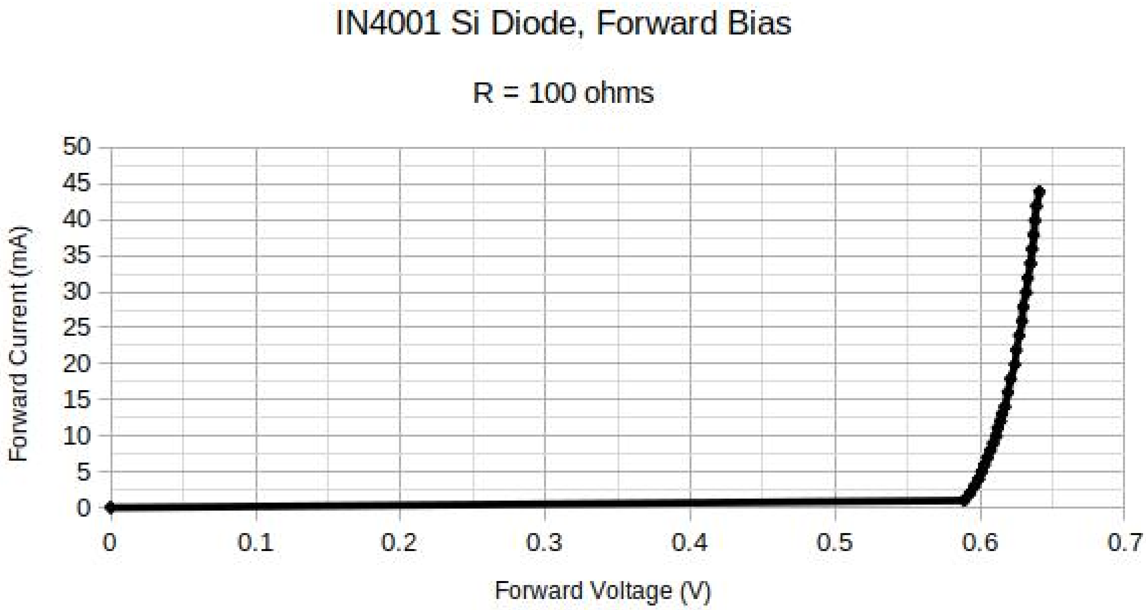

Figure 3: IN4001 Si Diode, Forward Bias, R = 100Ω

2. Resistance, R = 500Ω

S.No.	V_{dc}	$V_f(V)$	$I_f(mA)$	**Static Resistance (x$10^3\Omega$)**
01	0	0	0	N.A
02	0.2	0	0	N.A
03	0.7	0.548	0.200	2.74
04	1.0	0.557	0.800	0.696
05	1.3	0.564	1.40	0.4028
06	1.6	0.569	2.00	0.2845
07	1.9	0.574	2.60	0.2207
08	2.2	0.577	3.20	0.1803
09	2.5	0.581	3.80	0.2075
10	2.8	0.584	4.40	0.1332
11	3.1	0.586	5.00	0.117
12	3.4	0.598	5.60	0.1051
13	3.7	0.591	6.20	0.0953
14	4.0	0.593	6.80	0.0872
15	4.3	0.595	7.40	0.074625
16	4.6	0.597	8.00	0.0745
17	4.9	0.598	8.59	0.069

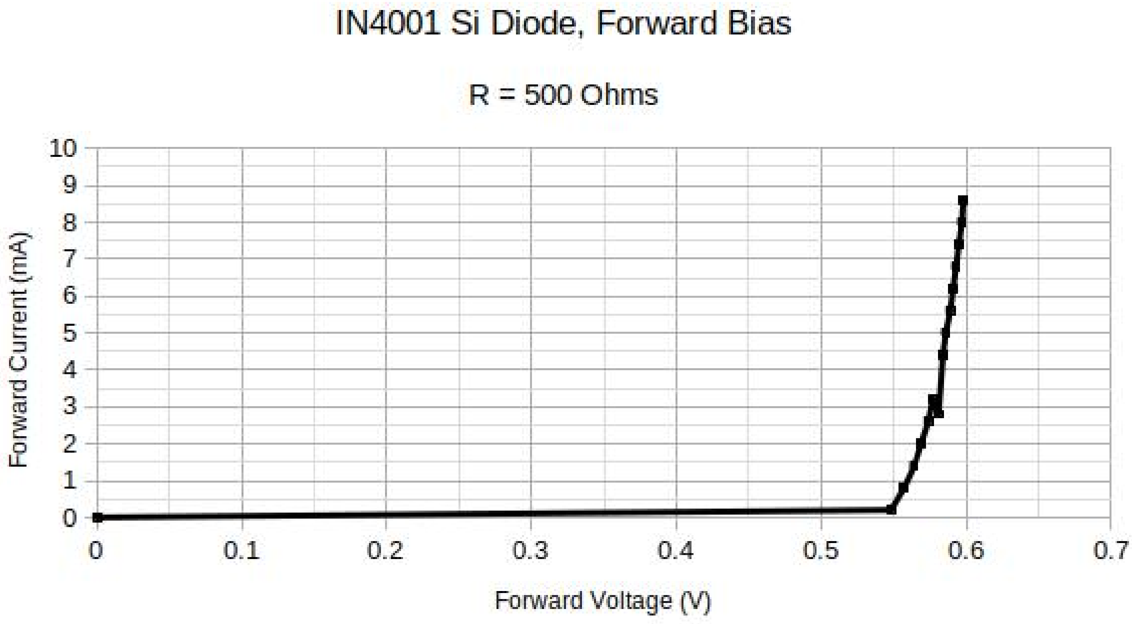

Figure 4: IN4001 Si Diode, Forward Bias, R = 500Ω

3. Resistance, R = 2000Ω

S.No.	V_{dc}	$V_f(V)$	$I_f(mA)$	**Static Resistance (x$10^3\Omega$)**
01	0	0	0	N.A.
02	0.2	0	0	N.A.
03	0.7	0.512	0.05	10.24
04	1.0	0.521	0.20	2.605
05	1.3	0.528	0.35	1.508
06	1.6	0.533	0.50	1.066
07	1.9	0.537	0.650	0.826
08	2.2	0.541	0.80	0.6726
09	2.5	0.545	0.950	0.573
10	2.8	0.548	1.10	0.498
11	3.1	0.550	1.25	0.44
12	3.4	0.553	1.40	0.395
13	3.7	0.555	1.55	0.358
14	4.0	0.557	1.70	0.327
15	4.3	0.559	1.85	0.302
16	4.6	0.560	2.00	0.28
17	4.9	0.562	2.15	0.2613

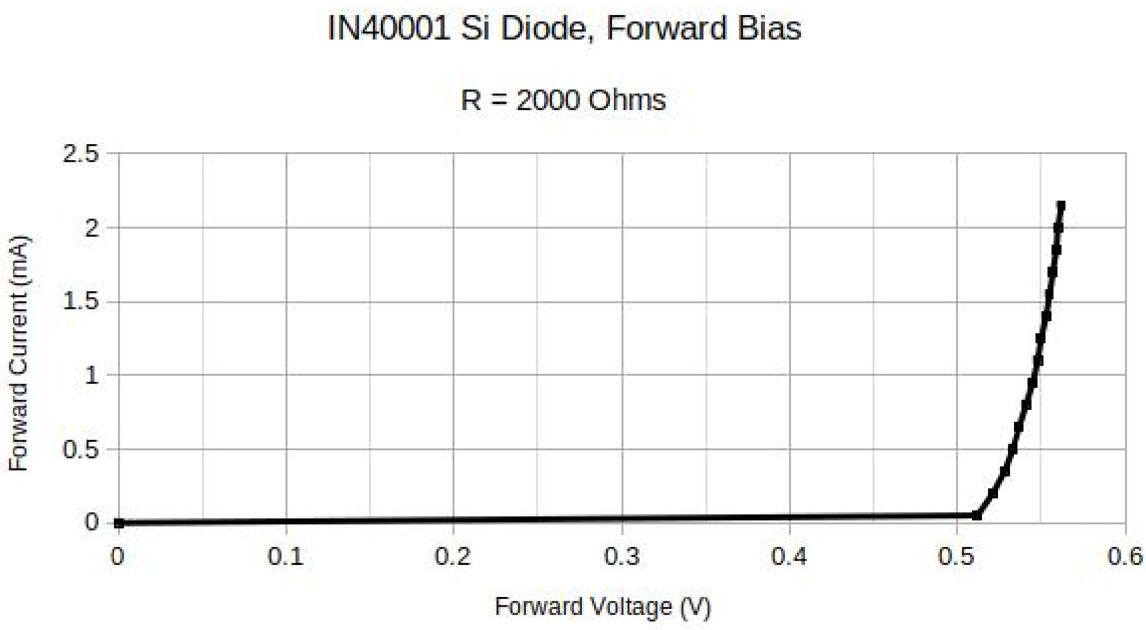

Figure 5: IN4001 Si Diode, Forward Bias, R = 2000Ω

- Reverse Bias
  Resistance, $R = 100\Omega$

S.No.	V_{dc}	$V_r(V)$	$I_r(\mu A)$	**Static Resistance (x**$10^6\Omega$**)**
01	0.2	0.170	0.100	1.7
02	0.35	303	0.100	3.03
03	0.50	0.439	0.100	4.39
04	0.90	0.807	0.100	8.07
05	1.5	1.37	0.100	13.7
06	2.0	1.84	0.100	18.4
07	3.0	2.80	0.100	28
08	4.0	3.77	0.100	37.7
09	6.0	5.73	0.100	57.3
10	8.0	5.52	0.100	77.2
11	10.0	9.71	0.100	97.1
12	15.0	14.8	0.100	148
13	20.0	19.9	0.100	199
14	25.0	25.0	0.100	250
15	29.0	29.1	0.100	291
16	30.0	30.2	75.00	—
17	30.1	30.3	75.25	—
18	30.15	30.3	75.37	—
19	30.2	30.4	75.50	—

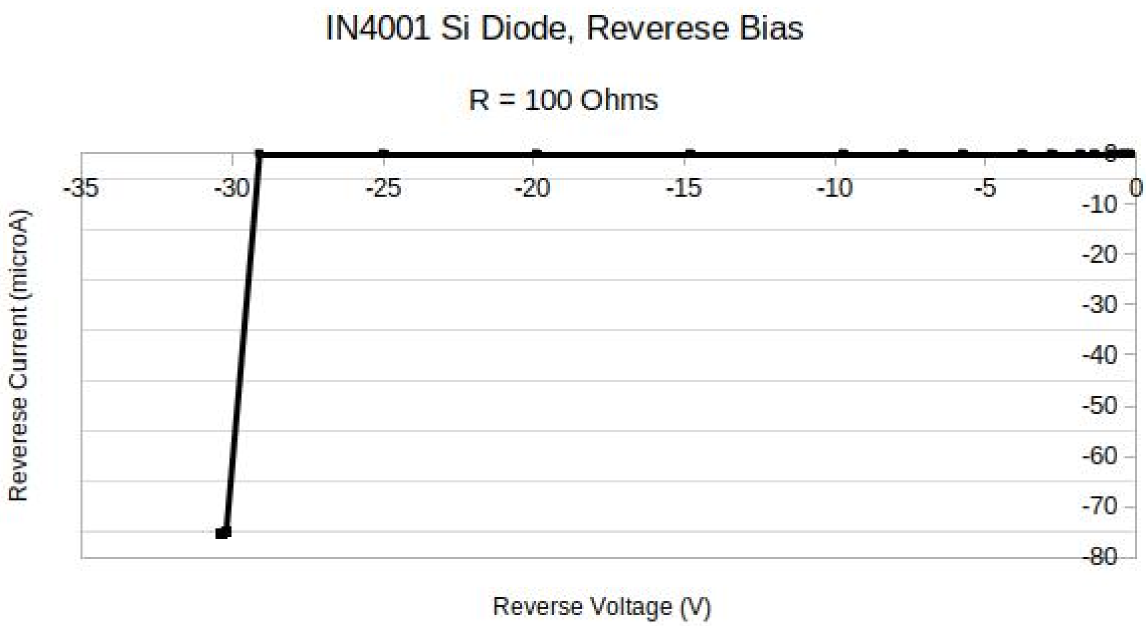

Figure 6: IN4001 Si Diode, Reverse Bias, R = 100Ω

6.2 Germanium Diode

- Forward Bias
  Resistance, R = 1000Ω

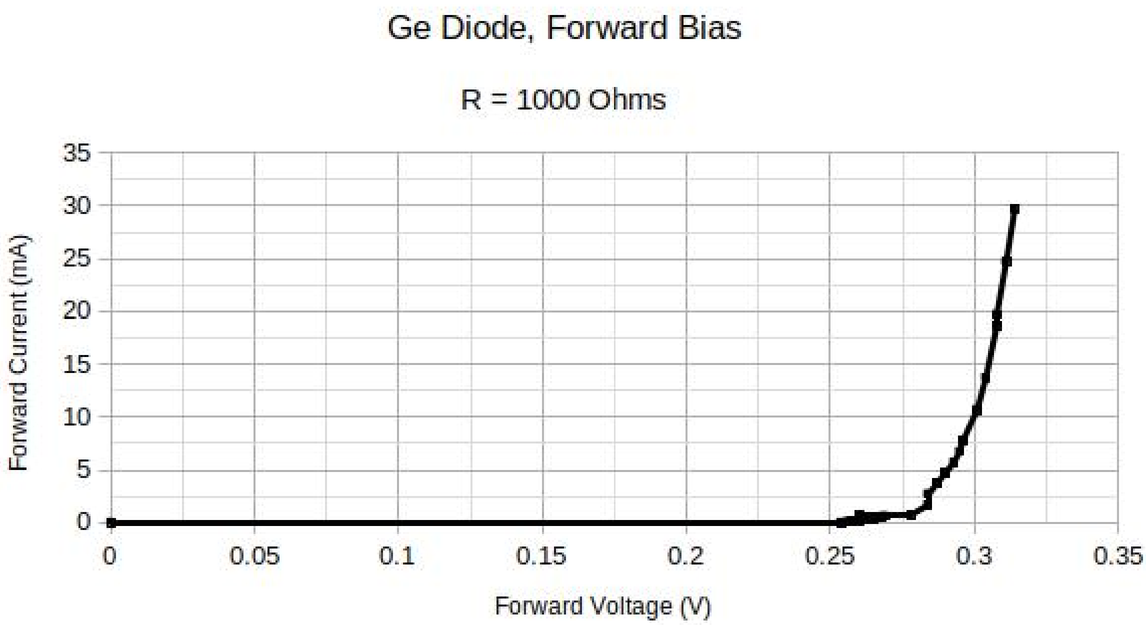

Figure 7: Ge Diode, Forward Bias, R = 1000Ω

S.No.	V_{dc}	$V_f(V)$	$I_f(mA)$	**Static Resistance (x$10^3\Omega$)**
01	0	0	0	N.A.
02	0.2	0	0	N.A.
03	0.3	0.254	0	5.12
04	0.35	0.256	0.050	2.57
05	0.4	0.257	0.100	1.72
06	0.45	0.259	0.150	1.3
07	0.50	0.260	0.200	1.048
08	0.55	0.262	0.250	0.876
09	0.60	0.263	0.300	0.754
10	0.65	0.264	0.350	0.662
11	0.70	0.265	0.400	0.5911
12	0.75	0.266	0.450	0.534
13	0.80	0.267	0.500	0.487
14	0.85	0.267	0.550	0.448
15	0.90	0.268	0.600	0.4
16	0.95	0.269	0.650	0.397
17	1.00	0.278	0.700	0.167
18	2.00	0.284	1.70	0.105
19	3.00	0.287	2.70	0.077
20	4.00	0.290	3.70	0.061
21	5.00	0.293	4.70	0.051
22	6.00	0.295	5.70	0.044
23	7.00	0.296	6.70	0.038
24	8.00	0.301	7.70	0.028
25	11.00	0.304	10.70	0.022
26	14.00	0.308	13.70	0.016
27	19.00	0.308	18.70	0.015
28	20.00	0.311	19.70	0.0125
29	25.00	0.314	24.70	0..011
30	30.00	0.641	29.70	0.0105

- Reverse Bias
  Resistance, R = 1000Ω

S.No.	V_{dc}	$V_r(V)$	$I_r(mA)$	**Static Resistance (x$10^3\Omega$)**
01	0.2	0.2	0	N.A.
02	0.25	0.25	0	N.A.
03	0.3	0.3	0	N.A.
04	2	2.0	0	N.A.
05	3	3.0	0	N.A.
06	4	4.0	0	N.A.
07	10	10.0	0	N.A.
08	20	20.0	0	N.A.
09	29.95	29.9	0	N.A.
10	30	30.0	30	—
11	30.05	30.1	30.05	—
12	30.1	30.1	30.10	—
13	30.15	30.1	30.15	—
14	30.2	30.2	30.19	—

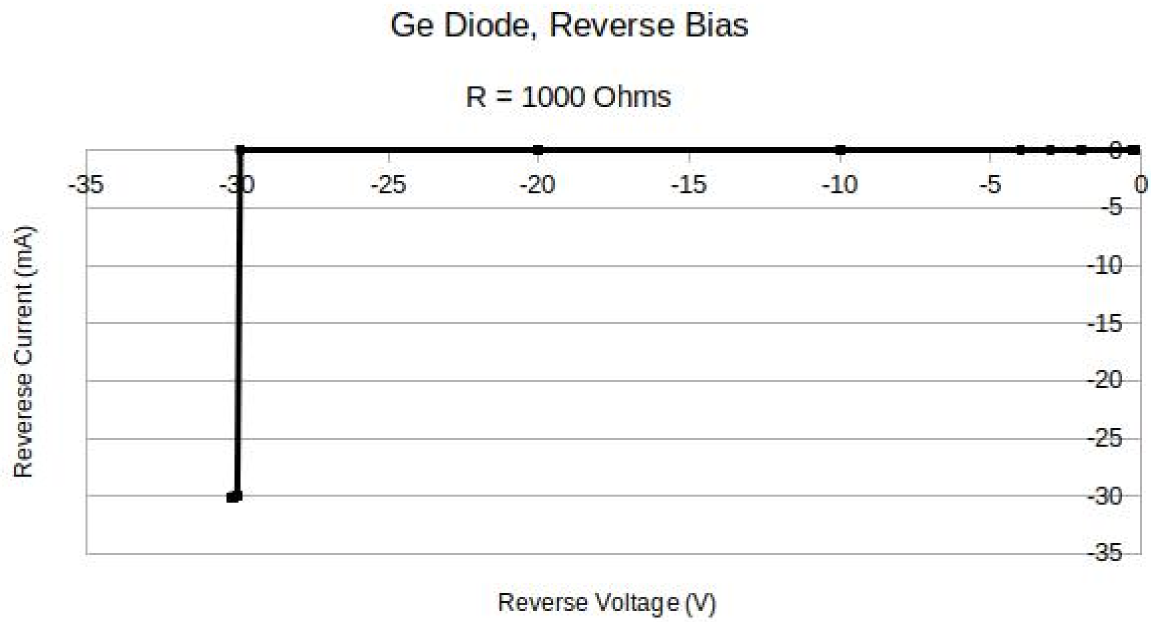

Figure 8: Ge Diode, Reverse Bias, R = 1000Ω

7 Analysis

The static resistances have been calculated for specific diode currents in the previous section (tables). Dynamic resistances haven't been calculated since they are usually used in AC circuits (and the circuit in the simulator was a DC one).