EECS 312 – Electronic Circuits I – Notes
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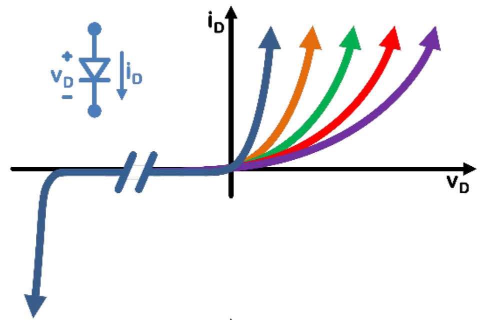
Zener Diodes and Voltage Regulators

A voltage regulator constructed using the ~0.7V forward bias voltage drop across a diode is designed using the following equations:

number of diodes: $N = V_R/0.7$

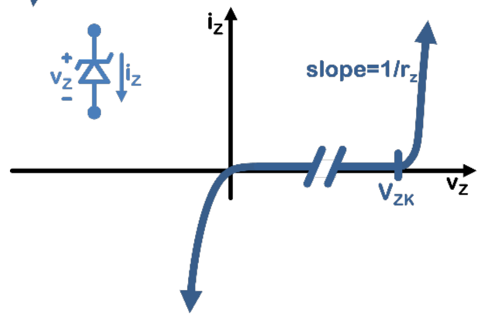
line regulation: $\Delta v_r/\Delta v_s = N\times r_d/(N\times r_d+R_S)$

The problem is that for larger regulated voltages many diodes must be used resulting in poor line regulation. The current-voltage characteristic is shown in the plot for N = 1 to 5. As N increases the slope decreases resulting in a larger resistance.



The plot also shows the breakdown region for a single diode, which exhibits a large turn on voltage and steep fairly constant slope. A Zener diode is exactly the same as a normal junction diode except:

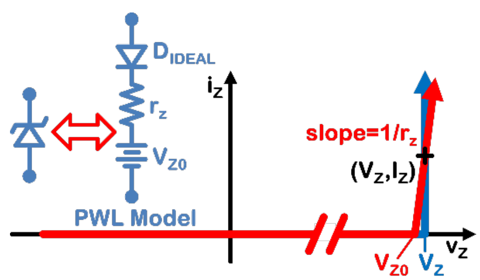
1. The voltage and current orientations are reversed.
2. The diode symbol has edges on the line.
3. The datasheet specifies additional information for the breakdown region.



The Zener diode can be modeled using the CVD model or with the addition of a small resistor. The resistor accounts for the constant slope of the i-v curve in breakdown. The resulting current voltage characteristic for the PWL model becomes:

$i_z=0$ for $v_z<V_{Z0}$

$i_z=(v_Z-V_{Z0})/r_z$ for $v_z>V_{Z0}$



Care should be taken with Zener diodes that v_z does not become negative to go into the FB region.

Electrical Characteristics T_a = 25°C unless otherwise noted

Device	V_Z (V) @ I_Z (Note 1)			Test Current I_Z (mA)	Max. Zener Impedance			Leakage Current		Non-Repetitive Peak Reverse Current
	Min.	Typ.	Max.		Z_Z@I_Z (Ω)	Z_{ZK} @ I_{ZK} (Ω)	I_{ZK} (mA)	I_R (μA)	V_R (V)	I_{ZSM} (mA) (Note 2)
1N4728A	3.135	3.3	3.465	76	10	400	1	100	1	1380
1N4729A	3.42	3.6	3.78	69	10	400	1	100	1	1260
1N4730A	3.705	3.9	4.095	64	9	400	1	50	1	1190
1N4731A	4.085	4.3	4.515	58	9	400	1	10	1	1070
1N4732A	4.465	4.7	4.935	53	8	500	1	10	1	970
1N4733A	4.845	5.1	5.355	49	7	550	1	10	1	890
1N4734A	5.32	5.6	5.88	45	5	600	1	10	2	810
1N4735A	5.89	6.2	6.51	41	2	700	1	10	3	730
1N4736A	6.46	6.8	7.14	37	3.5	700	1	10	4	660
1N4737A	7.125	7.5	7.875	34	4	700	0.5	10	5	605
1N4738A	7.79	8.2	8.61	31	4.5	700	0.5	10	6	550
1N4739A	8.645	9.1	9.555	28	5	700	0.5	10	7	500
1N4740A	9.5	10	10.5	25	7	700	0.25	10	7.6	454
1N4741A	10.45	11	11.55	23	8	700	0.25	5	8.4	414
1N4742A	11.4	12	12.6	21	9	700	0.25	5	9.1	380

The table (https://www.onsemi.com/pub/Collateral/1N4736AT-D.PDF) shows values for Zener diodes. The 12V device (1N4742A) has r_z = 9Ω, and a test current, $I_Z(V_Z=12V)$ = 21mA. Based on these values, we can find $V_{Z0} = 12 - 9\times.021 = 11.81V$. As a comparison, a 12V regulator based on N×FB diodes (n=2) would require 12/0.7 = 17 diodes. If V_S = 14V and R_S = 200Ω, the regulator would have total diode resistance of 80Ω and a line regulation of 0.28. The Zener diode approach would require one diode and have a line regulation of 0.04.