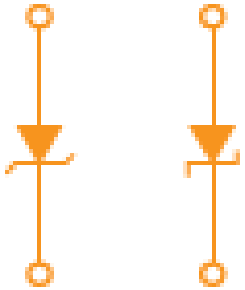
Zener diodes

Zener Diode

- Small-signal and rectifier diodes cannot be operated in the breakdown region as it may damage them.

- Zener diode operates in the breakdown region

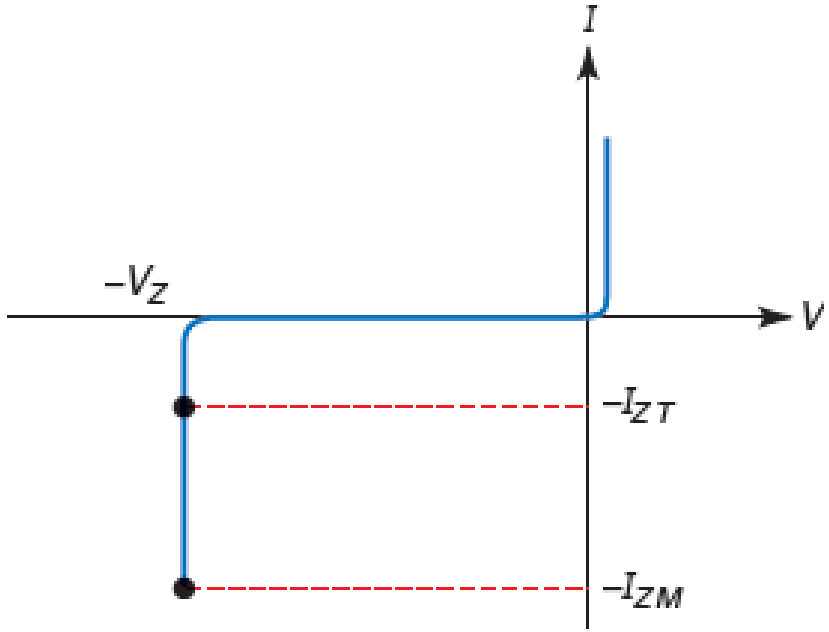


- By varying the doping level of silicon diodes, a manufacturer can produce zener diodes with breakdown voltages from about 2 to over 1000 V.

- Zener diodes operate in any of three regions: forward, leakage, and breakdown.

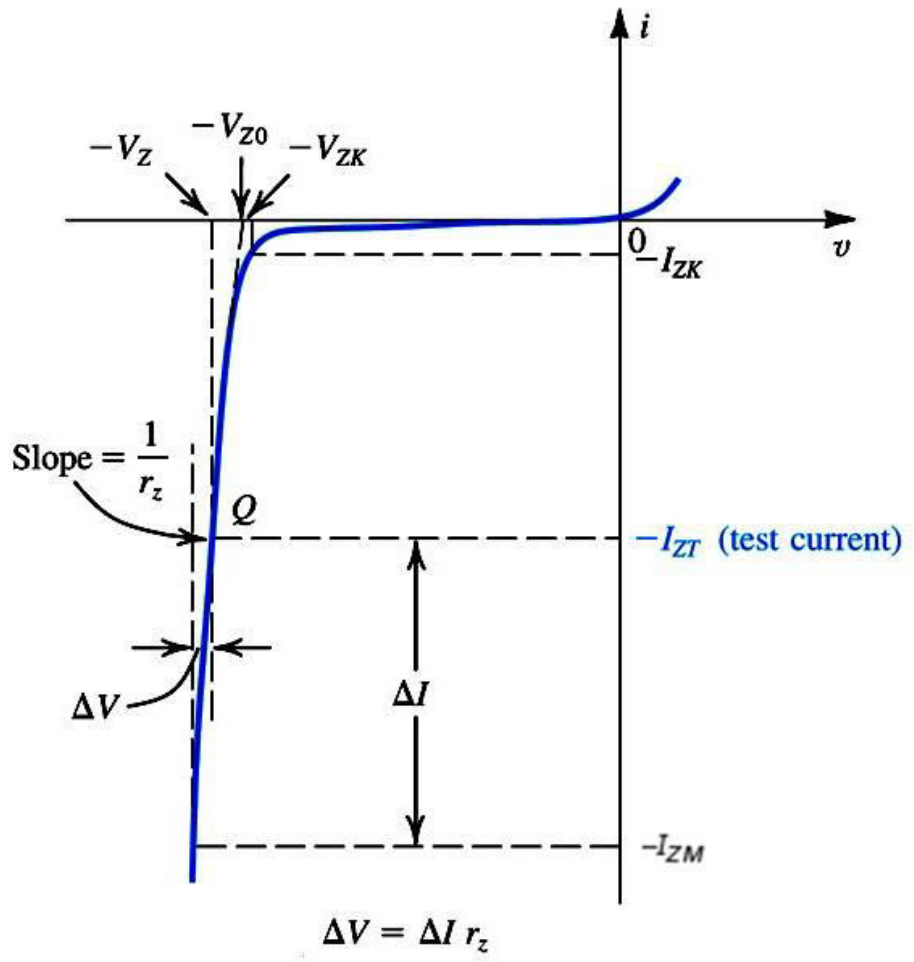
Characteristics of Zener Diode

- **Forward region -** conduction starts around 0.7 V, like a ordinary silicon diode.
- **Leakage region** (between zero and breakdown) - only a small reverse current flows.
- **Breakdown region** - has very sharp knee, followed by almost vertical increase in current.
- Voltage is almost constant, approximately equal to V_Z over most of the breakdown region



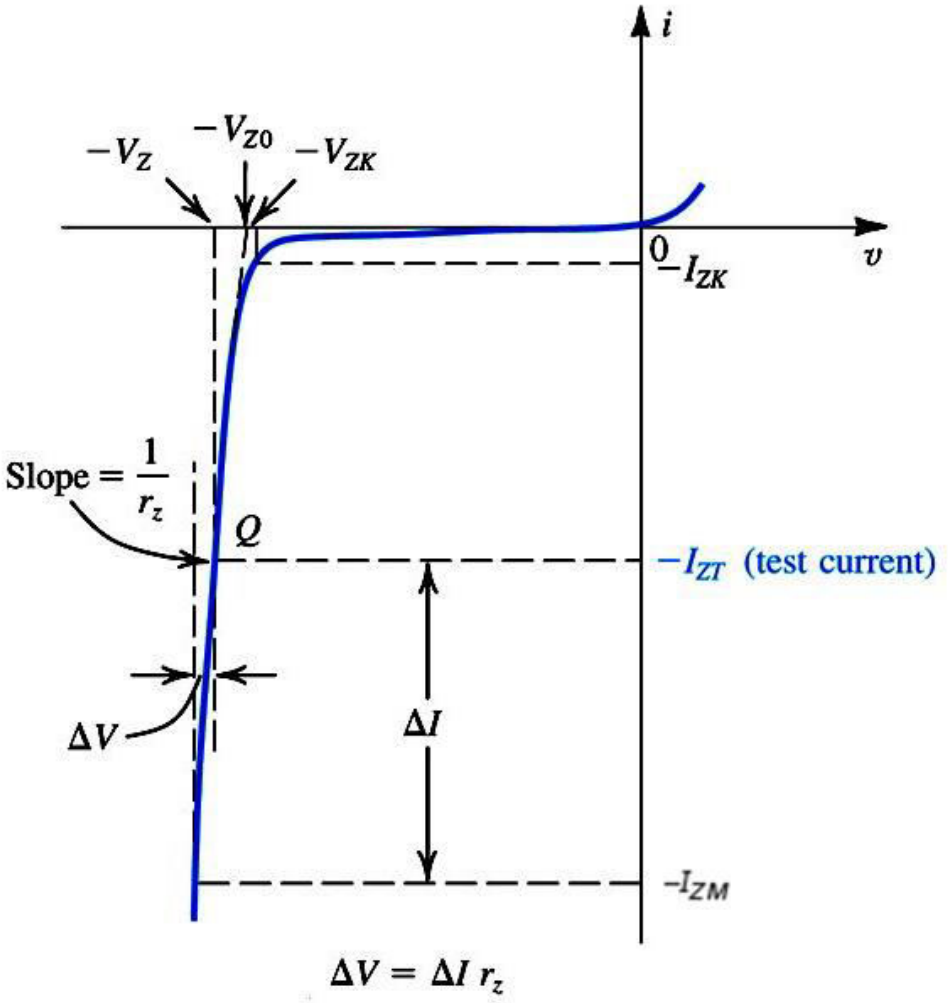
Characteristics of Zener Diode

- V_Z at a particular test current I_{ZT}
- Maximum reverse current I_{ZM}
- As long as the reverse current is less than I_{ZM}, the diode is operating within its safe range.
- If the current is greater than I_{ZM}, the diode will be destroyed.
- To prevent excessive reverse current, a current-limiting resistor must be used



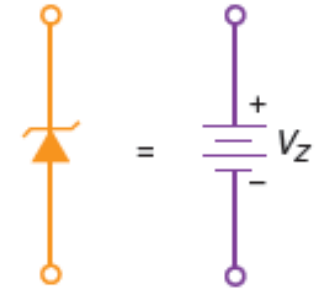
Zener Resistance

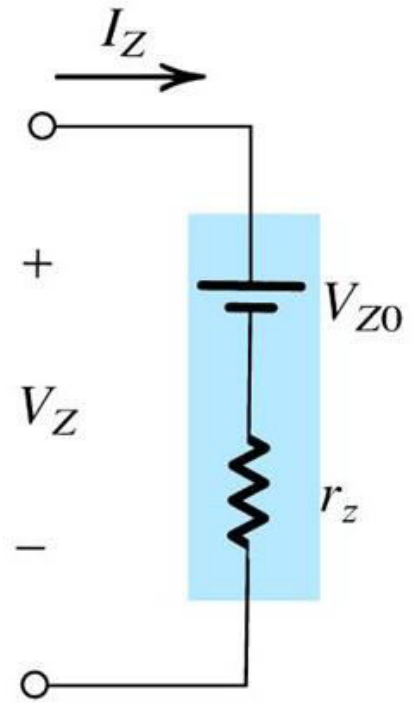
- Increase in reverse current produces a slight increase in reverse voltage.
- The increase in voltage is very small, typically only a few tenths of a volt
- Zener resistance equals the inverse of the slope in the breakdown region



Ideal Zener diode

- Breakdown region can be approximated as vertical.
- Therefore, the voltage is constant even though the current changes, which is equivalent to ignoring the Zener resistance.
- A Zener diode operating in the breakdown region ideally acts like a battery

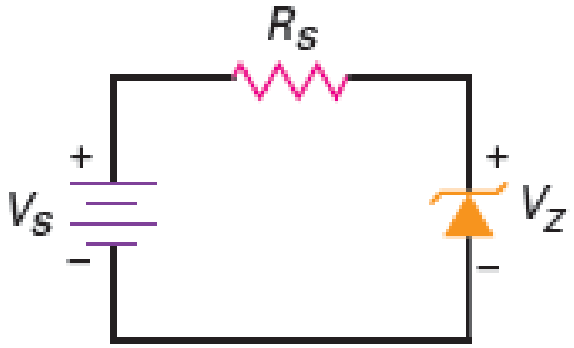


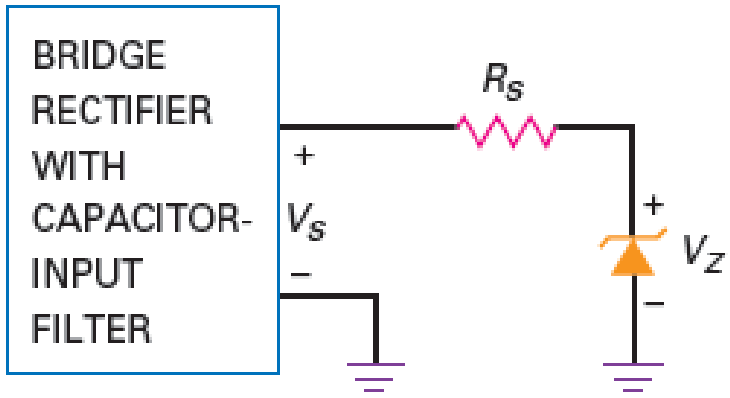


$$V_Z = V_{Z0} + r_Z I_Z$$

Zener Regulator

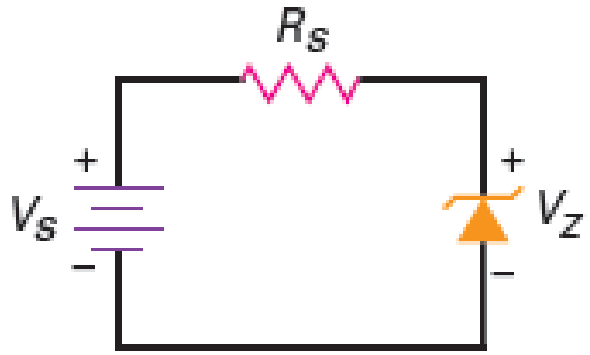
- Known as Voltage-regulator diode as it maintains a constant output voltage even though the current through it changes.
- For normal operation, Zener is reverse-biased
- To get breakdown operation, the source voltage V_S must be greater than the zener breakdown voltage V_Z.
- A series resistor R_S is always used to limit the zener current to less than its maximum current rating, otherwise, diode will burn out due to too much power dissipation





Zener Regulator

- Zener voltage regulator, or zener regulator
- The voltage across the series or current-limiting resistor equals the difference between the source voltage and the Zener voltage



$$I_S = \frac{V_S - V_Z}{R_S}$$

$$R_{S(\max)} = \frac{V_{S(\min)} - V_Z}{I_{L(\max)}}$$

Loaded Zener Regulator

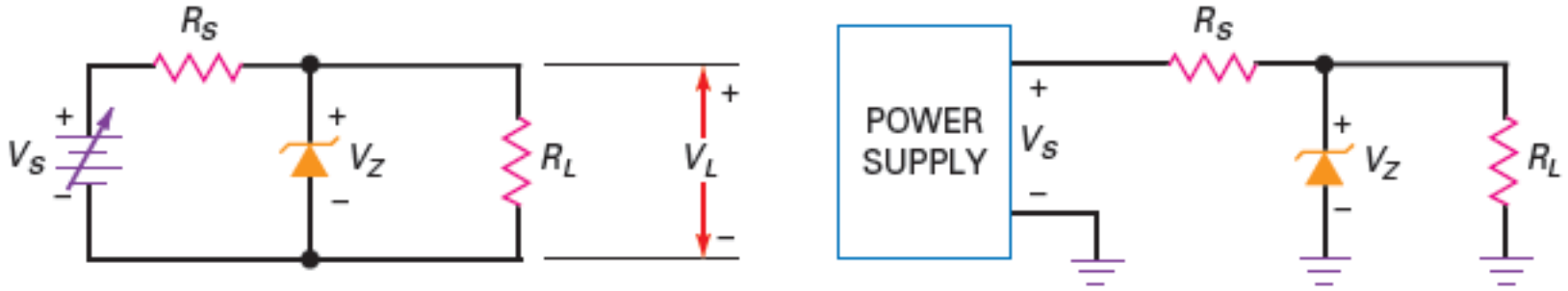
- **Breakdown operation**

$$V_{TH} = \frac{R_L}{R_S + R_L} V_S$$

Thevenin voltage has to be greater than the zener voltage; otherwise, breakdown cannot occur

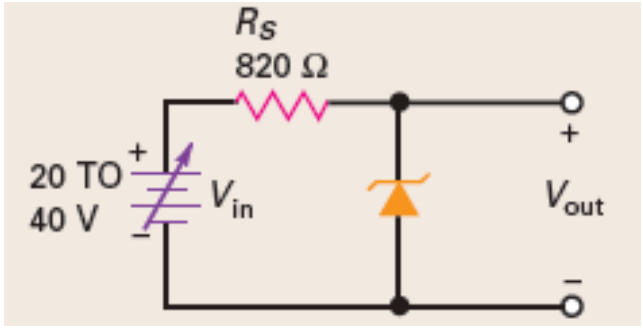
- **Load Current -** the load voltage equals the zener voltage because the load resistor is in parallel with the zener diode.

$$V_L = V_Z \qquad I_L = \frac{V_L}{R_L}$$



Problem #1

Suppose the zener diode shown has a breakdown voltage of 10 V. What are the minimum and maximum zener currents?



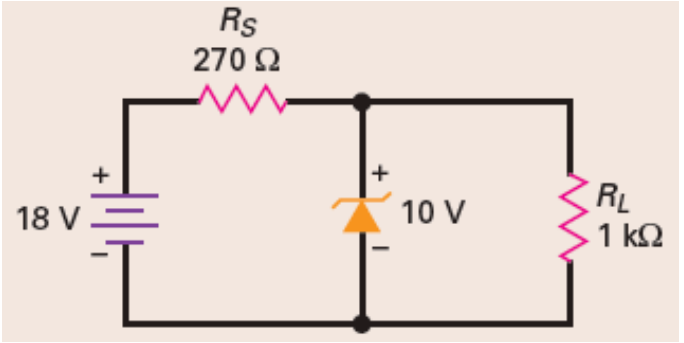
Solution:

$$I_S = \frac{10\text{ V}}{820\ \Omega} = 12.2\text{ mA}$$

$$I_S = \frac{30\text{ V}}{820\ \Omega} = 36.6\text{ mA}$$

Problem #2

Is the zener diode shown below operating in the breakdown region?



Solution:

$$V_{TH} = \frac{1\ \text{k}\Omega}{270\ \Omega + 1\ \text{k}\Omega}(18\ \text{V}) = 14.2\ \text{V}$$

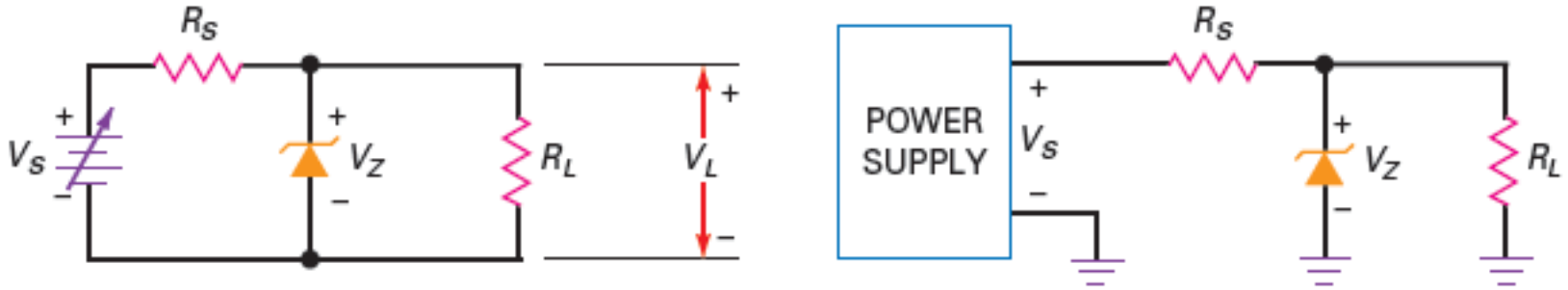
zener diode is operating in the breakdown region

Loaded Zener Regulator

- **Zener Current –** With Kirchhoff's current law

$$I_S = I_Z + I_L$$

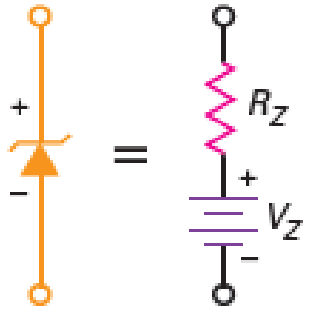
$$I_Z = I_S - I_L$$



Zener Equivalent Circuit

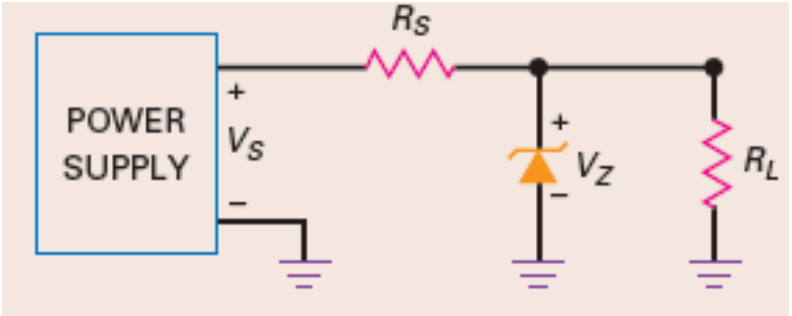
- Zener current flows through the zener resistance, the load voltage is given by

$$V_L = V_Z + I_Z R_Z$$



Problem #3

The zener diode Shown has a breakdown voltage of 10 V and a zener resistance of 8.5 Ω. Calculate the load voltage when the zener current is 20 mA.



Solution:

$$V_L = 10\ \text{V} + 0.17\ \text{V} = 10.17\ \text{V}$$

Reading a Data Sheet

FAIRCHILD SEMICONDUCTOR

July 2013

1N5221B - 1N5263B
Zener Diodes

Tolerance = 5%

DO-35 Glass case
COLOR BAND DENOTES CATHODE

1N5221B - 1N5263B — Zener Diodes

Absolute Maximum Ratings

Symbol	Parameter	Value	Units
P_D	Power Dissipation	500	mW
	Derate above 50°C	4.0	mW°C
T_{STG}	Storage Temperature Range	-65 to +200	°C
T_J	Operating Junction Temperature Range	-65 to +200	°C
	Lead Temperature (1/16 inch from case for 10 s)	+230	°C

Electrical Characteristics

Values are at T_A = 25°C unless otherwise noted .

Device	V_Z (V) @ I_Z [2]			Z_Z (Ω) @ I_Z (mA)		Z_{ZK} (Ω) @ I_{ZK}(mA)		I_R (μA) @ V_R (V)		T_C (%/°C)
	Min.	Typ.	Max.							
1N5221B	2.28	2.4	2.52	30	20	1,200	0.25	100	1.0	-0.085
1N5222B	2.375	2.5	2.625	30	20	1,250	0.25	100	1.0	-0.085
1N5223B	2.565	2.7	2.835	30	20	1,300	0.25	75	1.0	-0.080
1N5224B	2.66	2.8	2.94	30	20	1,400	0.25	75	1.0	-0.080
1N5225B	2.85	3	3.15	29	20	1,600	0.25	50	1.0	-0.075
1N5226B	3.135	3.3	3.465	28	20	1,600	0.25	25	1.0	-0.07
1N5227B	3.42	3.6	3.78	24	20	1,700	0.25	15	1.0	-0.065
1N5228B	3.705	3.9	4.095	23	20	1,900	0.25	10	1.0	-0.06
1N5229B	4.085	4.3	4.515	22	20	2,000	0.25	5.0	1.0	+/-0.055
1N5230B	4.465	4.7	4.935	19	20	1,900	0.25	2.0	1.0	+/-0.03
1N5231B	4.845	5.1	5.355	17	20	1,600	0.25	5.0	2.0	+/-0.03
1N5232B	5.32	5.6	5.88	11	20	1,600	0.25	5.0	3.0	0.038
1N5233B	5.7	6	6.3	7.0	20	1,600	0.25	5.0	3.5	0.038
1N5234B	5.89	6.2	6.51	7.0	20	1,000	0.25	5.0	4.0	0.045
1N5235B	6.46	6.8	7.14	5.0	20	750	0.25	3.0	5.0	0.05
1N5236B	7.125	7.5	7.875	6.0	20	500	0.25	3.0	6.0	0.058
1N5237B	7.79	8.2	8.61	8.0	20	500	0.25	3.0	6.5	0.062
1N5238B	8.265	8.7	9.135	8.0	20	600	0.25	3.0	6.5	0.065
1N5239B	8.645	9.1	9.555	10	20	600	0.25	3.0	7.0	0.068
1N5240B	9.5	10	10.5	17	20	600	0.25	3.0	8.0	0.075
1N5241B	10.45	11	11.55	22	20	600	0.25	2.0	8.4	0.076
1N5242B	11.4	12	12.6	30	20	600	0.25	1.0	9.1	0.077
1N5243B	12.35	13	13.65	13	9.5	600	0.25	0.5	9.9	0.079
1N5244B	13.3	14	14.7	15	9.0	600	0.25	0.1	10	0.080
1N5245B	14.25	15	15.75	16	8.5	600	0.25	0.1	11	0.082
1N5246B	15.2	16	16.8	17	7.8	600	0.25	0.1	12	0.083
1N5247B	16.15	17	17.85	19	7.4	600	0.25	0.1	13	0.084
1N5248B	17.1	18	18.9	21	7.0	600	0.25	0.1	14	0.085
1N5249B	18.05	19	19.95	23	6.6	600	0.25	0.1	14	0.085
1N5250B	19	20	21	25	6.2	600	0.25	0.1	15	0.086

V_F Forward Voltage = 1.2V Max. @ I_F = 200mA

Note:

1. These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.
   Non-recurrent square wave Pulse Width = 8.3 ms, T_A = 50°C
2. Zener Voltage (V_Z)
   The zener voltage is measured with the device junction in the thermal equilibrium at the lead temperature (T_L) at 30°C ± 1°C and 3/8" lead length.

FAIRCHILD SEMICONDUCTOR

April 2009

1N4728A - 1N4758A
Zener Diodes

Tolerance = 5%

DO-41 Glass case
COLOR BAND DENOTES CATHODE

1N4728A - 1N4758A — Zener Diodes

Absolute Maximum Ratings * T_a = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
P_D	Power Dissipation @ TL ≤ 50°C, Lead Length = 3/8"	1.0	W
	Derate above 50°C	6.67	mW/°C
T_J, T_{STG}	Operating and Storage Temperature Range	-65 to +200	°C

* These ratings are limiting values above which the serviceability of the diode may be impaired.

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
1N4743A	12.35	13	13.65	19	10	700	0.25	5	9.9	344
1N4744A	14.25	15	15.75	17	14	700	0.25	5	11.4	304
1N4745A	15.2	16	16.8	15.5	16	700	0.25	5	12.2	285
1N4746A	17.1	18	18.9	14	20	750	0.25	5	13.7	250
1N4747A	19	20	21	12.5	22	750	0.25	5	15.2	225
1N4748A	20.9	22	23.1	11.5	23	750	0.25	5	16.7	205
1N4749A	22.8	24	25.2	10.5	25	750	0.25	5	18.2	190
1N4750A	25.65	27	28.35	9.5	35	750	0.25	5	20.6	170
1N4751A	28.5	30	31.5	8.5	40	1000	0.25	5	22.8	150
1N4752A	31.35	33	34.65	7.5	45	1000	0.25	5	25.1	135
1N4753A	34.2	36	37.8	7	50	1000	0.25	5	27.4	125
1N4754A	37.05	39	40.95	6.5	60	1000	0.25	5	29.7	115
1N4755A	40.85	43	45.15	6	70	1500	0.25	5	32.7	110
1N4756A	44.65	47	49.35	5.5	80	1500	0.25	5	35.8	95
1N4757A	48.45	51	53.55	5	95	1500	0.25	5	38.8	90
1N4758A	53.2	56	58.8	4.5	110	2000	0.25	5	42.6	80

Notes:

1. Zener Voltage (V_Z)
   The zener voltage is measured with the device junction in the thermal equilibrium at the lead temperature (T_L) at 30°C ± 1°C and 3/8" lead length.
2. 2 Square wave Reverse Surge at 8.3 msec soak time.

Device Specifications

Maximum Power dissipation

- equals the product of its voltage and current

$$P_Z = V_Z I_Z$$

Maximum Current, I_{ZM}

- zener diode can handle without exceeding its power rating

$$I_{ZM} = \frac{P_{ZM}}{V_Z}$$

Derating Factor

- Reduce the power rating of a device.