XMUT204 Electronic Design

Note 2d: Special Purpose Diode (Zener Diode)

1. Introduction to Zener Diode

Zener diode is a special junction diode. It allows controlled breakdown at specified voltage in reverse bias. We can use this specified voltage (V_Z) as a (relatively) stable voltage reference. Its potential uses are as voltage regulator and voltage reference. But, be aware of limitations of use of Zener diode before you use it in the circuit.

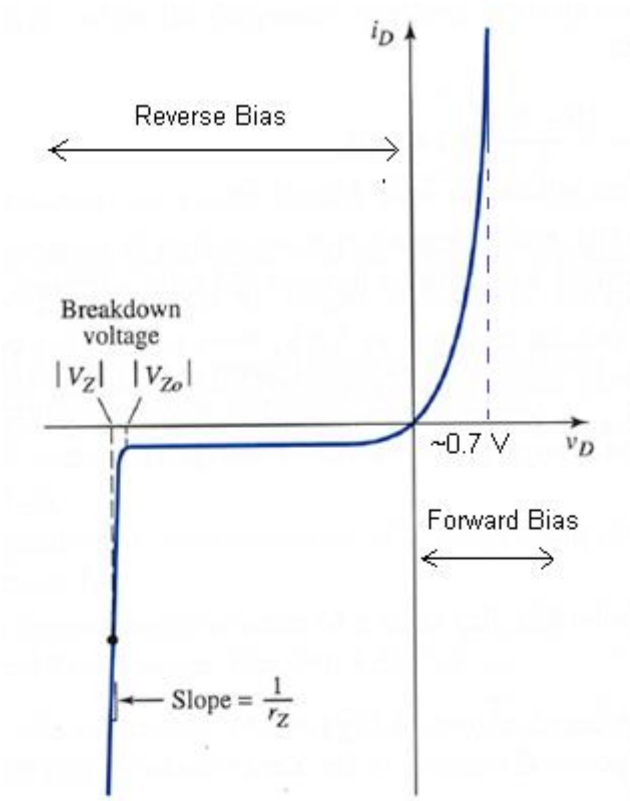


Figure 1: Current-voltage curve plot diagram for a Zener diode.

Consider reverse bias behaviour of a diode:

a. In the forward bias: it behaves as normal diode with switch on voltage drop at ~0.7 Volt (for silicon diode).
b. In reverse bias: if V_d < 0 but, V_d > V_z, the zener diode will be off. It acts as a normal reverse biased diode. No (very small) current flows.
c. When V_d << V_z (more negative), Zener diode will switch on (breakdown occurs) and the voltage V_d will remain at ~V_z.

Model of ideal Zener diode in a reverse bias is shown as per below:

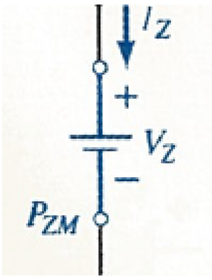


Figure 2: Model of ideal Zener diode in reverse bias.

Example for Tutorial 1 – Characteristics of Zener Diode

1. Describe three differences between Zener diode compared with conventional diode. [3 marks]

   Answer

   Three differences between Zener diode vs. conventional diode are:

   - Operated in the reversed bias mode: by design, Zener diode is designed to work in the reversed bias mode in which its anode is connected to the negative side of the voltage source and the cathode must be connected to the positive side.

   - Slope is steeper than conventional diode's slope: at reverse bias, the rate of change of the current against rate of change of the Zener diode is more pronounced than conventional diode.

   - Zener diode does not suffer from an avalanche breakdown, but a slightly different kind of breakdown which is called the Zener breakdown.

2. A Zener diode has an impedance of 5 Ω. What is its terminal voltage at 50 mA if $V_Z = 4.7$ V at $I_Z = 25$ mA? [2.5 marks]

   Answer:

   The impedance of the Zener diode is calculated from:

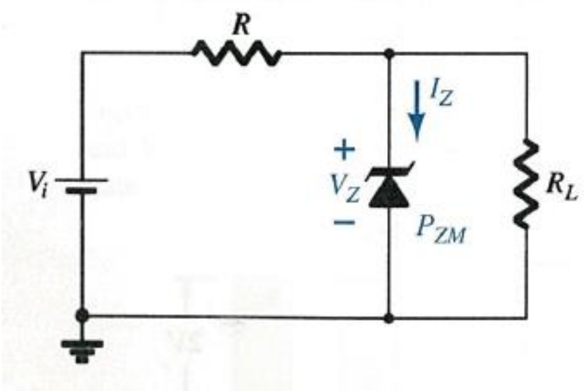
$$Z_z = \frac{\Delta V_Z}{\Delta I_Z} = \frac{V_{z2} - V_{z1}}{I_{z2} - I_{z1}}$$

   Rearranging the equation given above, the terminal voltage is:

$$V_{z2} = Z_z \times (I_{z2} - I_{z1}) + V_{z1} = 5 \times (50 \text{ mA} - 25 \text{ mA}) + 4.7 = 4.825 \text{ V}$$

Example for Tutorial 2 - Zener Diode Circuit (1N576A)

The following diagram shows a typical circuit with a 1N476A Zener diode application. In this circuit, we have: V_i = 5 V, R = 330 Ω, R_L = 50 Ω, and V_Z = 3.3 V.



a. How do we know if Zener is on? [4 marks]

b. Change value of the load resistor (50 Ω to 1 kΩ). Is Zener diode on? Calculate all voltages and currents in the circuit. [24 marks]

c. Determine the power ratings of the devices e.g. Zener diode and resistor. [6 marks]

d. Determine power rating of the diode (operated at 50°C). [4 marks]

e. Increase again the value of load resistance (1 kΩ to 10 kΩ). Is Zener diode on? Calculate all voltages and currents in the circuit. [24 marks]

Answer

a. We know that for the given circuit:

Voltage over diode (V_D) = Voltage over load resistor (V_{R_L})

Remove diode from the circuit (open circuit) and calculate V_{R_L} (e.g. voltage divider circuit):

$$V_{R_L} = \left(\frac{R_L}{R + R_L}\right) V_i$$

Taking the values of the components involved in the circuit:

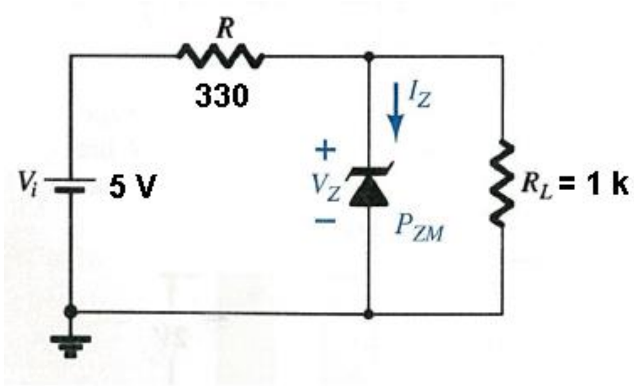
$$V_{R_L} = \left(\frac{50\ \Omega}{330\ \Omega + 50\ \Omega}\right) \times 5\ \text{V} = 0.66\ \text{V}$$

As a result, $V_{R_L} = V_D = 0.66\ \text{V}$ which will not be enough to turn a Zener diode (Vz = 3.3 V). This will act as if Zener diode does not exist in the circuit.

Electrical Characteristics T_A=25°C unless otherwise noted

Device	V_Z (V) @ I_Z = 20mA (Note 1)			Z_Z (Ω) @ I_Z = 20mA	I_{ZM} (mA) (Note 2)	I_R (μA) @ V_R = 1V	
	Min.	Typ.	Max.			Ta = 25°C	Ta = 125°C
1N4370A	2.28	2.4	2.52	30	150	100	200
1N4371A	2.57	2.7	2.84	30	135	75	150
1N4372A	2.85	3.0	3.15	29	120	50	100
1N746A	3.14	3.3	3.47	28	110	10	30
1N747A	3.42	3.6	3.78	24	100	10	30

b. If we change the load resistor from 50 Ω to 1 kΩ, then the circuit becomes as shown in the diagram given below.



The voltage across the load resistor, R can be found from the following equation:

$$V_{R_L} = \left(\frac{1\ \text{k}\Omega}{1\ \text{k}\Omega + 330\ \Omega}\right) \times 5\ \text{V} = 3.75\ \text{V}$$

As $V_{R_L} = V_D = 3.75$ V, this $V_D > V_Z$ (i.e. the turn on voltage of 1N746A Zener diode, $V_Z =$ 3.3 V), so the Zener diode will be sufficiently turned on.

If the diode is on, then the voltage across the diode is equal to:

$$V_d = V_z = V_{RL} = 3.3\ \text{V}$$

This will make a voltage drop across the limiting resistor, R.

$$V_R = 5\ \text{V} - 3.3\ \text{V} = 1.7\ \text{V}$$

Thus, the two resistors (e.g. R and R_L) will not act as a voltage divider anymore.

Hence, the current that flows in the limiting resistor, R is found to be:

$$I_R = \frac{V_R}{R} = \frac{1.7\ V}{330\ \Omega} = 5.15\ \text{mA}$$

This current will divide into two pathways:

a. A current through the load (I_{RL}).
b. A current through the Zener diode (I_Z).

Current through load resistor, R_L:

$$I_L = \frac{V_L}{R_L} = \frac{3.3\ V}{1\ \text{k}\Omega} = 3.3\ \text{mA}$$

This will give the current that flows through the Zener diode:

$$I_Z = 5.15\ \text{mA} - 3.3\ \text{mA} = 1.85\ \text{mA}$$

Power dissipated by limiting resistor, R:

$$P_R = V_R I_R = 1.7\ \text{V} \times 5.15\ \text{mA} = 8.8\ \text{mW}$$

Power dissipated by Zener diode:

$$P_Z = V_Z I_Z = 3.3\ \text{V} \times 1.85\ \text{mA} = 6.1\ \text{mW}$$

c. We must choose components that can safely dissipate this power.

Assume that the rating of the resistor is using standard resistor power:

$$P_R\ (\text{max}) = 0.25\ \text{Watt}$$

The Zener diode rating is found to be (e.g. IN746A Zener diode – see Appendix 1 for its partial datasheet):

$$P_Z\ (\text{max}) = 500\ \text{mW}$$

As a result, both power dissipations are well within limits.

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

Symbol	Parameter	Value	Units
P_D	Power Dissipation @ TL ≤ 75°C, Lead Length = 3/8"	500	mW
	Derate above 75°C	4.0	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.

d. The power rating is specified for a specific temperature, or up to a specific temperature.

Referring to the datasheet of the Zener diode, for IN746A this reads:

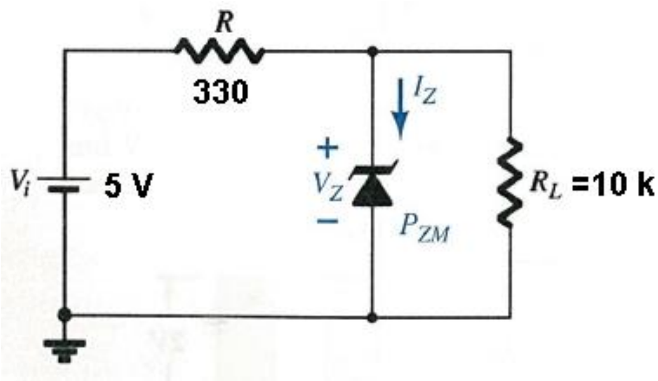
$$P_Z\ (\text{max}) = 500\ \text{mW @ 25°C}$$

If this temperature is exceeded, the power should be derated @ 3.33 mW/°C (for operating temperature up to 75°C).

If we expect the device to operate @ 50°C, the value for $P_Z(\text{max})$ will be:

$$P_Z(\text{max}) = 500\ \text{mW} - (50°\text{C} - 25°\text{C}) \times 3.33\ \text{mW/°C} = 418\ \text{mW}$$

e. If we change the load resistor from 1 kΩ to 10 kΩ, then the circuit becomes as shown in the diagram given below.



Is the Zener diode on?

$$V_{R_L} = \left(\frac{10\ \text{k}\Omega}{10\ \text{k}\Omega + 330\ \Omega}\right) \times 5\ \text{V} = 4.84\ \text{V}$$

Based on the result given above, the diode is found to be on.

Thus, the voltage across the diode is:

$$V_D = V_{R_L} = V_Z = 3.3\ \text{V}$$

Thus, the voltage across the 330 Ω limiting resistor, R:

$$V_R = 5\ \text{V} - 3.3\ \text{V} = 1.7\ \text{V}$$

Hence, the current that flows in the load resistor, R_L:

$$I_L = \frac{3.3\ \text{V}}{10\ \text{k}\Omega} = 0.33\ \text{mA}$$

The current in the limiting resistor, R:

I_R = (5 - 3.3)/330 = 5.15 mA

The current that flows through the Zener diode is:

$$I_Z = 5.15\ \text{mA} - 0.33\ \text{mA} = 4.82\ \text{mA}$$

As a result, the power that is dissipated across the Zener diode is:

$$P_Z = V_Z I_Z = 3.3\ \text{V} \times 4.82\ \text{mA} = 15.9\ \text{mW}$$

The power dissipation of the Zener diode increases as the load resistance increases. This should not exceed ~80% of the maximum power rating.

2. Reverse Bias of Zener Diode

If we look at the Zener diode reverse bias curve, the slope in the curve indicates a resistance is present.

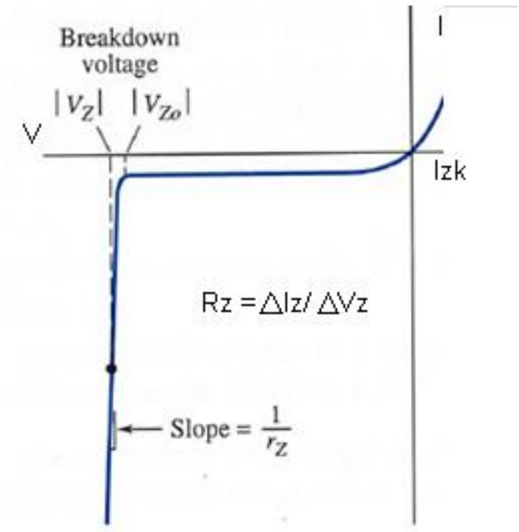


Figure 3: Reverse bias curve of Zener diode.

As a result, a better model for Zener diode in reverse bias is as shown in the figure below i.e. ideal diode model + voltage source + diode resistance.

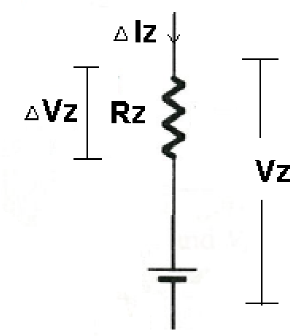
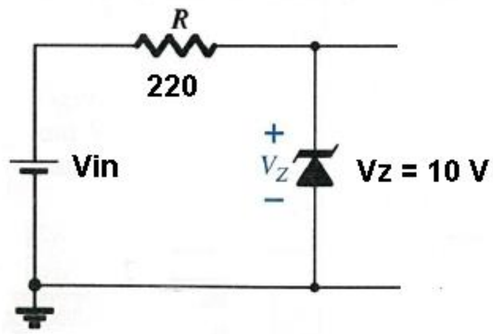


Figure 4: A better model of Zener diode.

Example for Tutorial 3 - Zener Diode Circuit (1N4740A)

For the following circuit given in the diagram below, the Zener diode is 1N4740A. Typical value for this diode: $\Delta V_Z = 50\ \mathrm{mV}$ and $\Delta I_Z = 5\ \mathrm{mA}$. This will give a Zener diode resistance:

$$R_Z = \frac{\Delta V_Z}{\Delta I_Z} = \frac{50\ \mathrm{mV}}{5\ \mathrm{mA}} = 10\ \Omega$$



For this analysis, we will consider a variable input voltage and evaluate the circuit based on this condition.

a. What is the minimum current in the circuit? [4 marks]

b. What is the maximum current in the circuit? [4 marks]

c. Determine the range of input voltage for Zener diode to turn on. [8 marks]

d. Describe how Zener diode is able to handle variable load. [4 marks]

e. What is the minimum load that the Zener diode can handle? [12 marks]

Answer

a. By referring to the datasheet of the given Zener diode, the lowest current that will ensure regulation when the Zener is on (I_{ZK}) is typically 0.25 mA for 1N4740A Zener diode (see Appendix 2 for its partial datasheet). This current is also considered as a no-load current.

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	
	Min.	Typ.	Max.		Z_Z @ I_Z (Ω)	Z_{ZK} @ I_{ZK} (Ω)	I_{ZK} (mA)	I_R (μA)	V_R (V)
1N4738A	7.79	8.2	8.61	31	4.5	700	0.5	10	6
1N4739A	8.645	9.1	9.555	28	5	700	0.5	10	7
1N4740A	9.5	10	10.5	25	7	700	0.25	10	7.6
1N4741A	10.45	11	11.55	23	8	700	0.25	5	8.4
1N4742A	11.4	12	12.6	21	9	700	0.25	5	9.1

b. This can be calculated from the maximum power of the Zener diode (as for 1N4740A Zener diode). From the datasheet, the maximum power dissipation of this diode is 1 W.

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.

The maximum current of the Zener diode is found from the following equation:

$$I_Z(\text{max}) = \frac{P_Z(\text{max})}{V_Z} = \frac{1\text{ W}}{10\text{ V}} = 100\text{ mA}$$

c. So, what is the maximum and minimum input voltage to operate Zener diode?

At no load, all current that flow through R also flows through Zener diode in this case.

For minimum current through Zener diode (i.e. I_{ZK} = 0.25 mA), the voltage drop across the limiting resistor, R is:

$$V_R = (0.25\text{ mA})(220\text{ V}) = 0.055\text{ V}$$

This will thus need the minimum input voltage is found to be:

$$V_{in}(\text{min}) = 10\text{ V} + 0.055\text{ V} = 10.055\text{ V}$$

From previous calculation, the maximum input voltage is determined by the maximum current through the Zener diode:

$$I_Z(\text{max}) = 100\text{ mA}$$

For this current, the voltage the voltage drop over limiting resistor R is:

$$V_R(\text{max}) = (100\text{ mA})(220\ \Omega) = 22\text{ V}$$

For the maximum input voltage, the input voltage is:

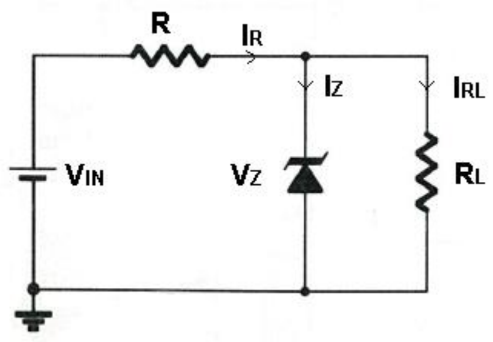
$$V_{in}(\text{max}) = V_R(\text{max}) + V_Z = 22\text{ V} + 10\text{ V} = 32\text{ V}$$

In practice, leave some decent safety margins e.g. $V_{in}(\text{min}) + 10\%$ and $V_{in}(\text{max}) - 20\%$.

This gives value in the range of 11 ~ 25 V.

d. With no load in place ($R_L = \infty$), all current flows through Zener at no load condition.

When load is connected, current is divided between the one flowing in the Zener diode and in the load.



The total current remains the same as long as Zener is on.

a. If the R_L is going up, as a result I_L is going down, and I_Z is going up.
b. If the R_L is going down, as a result I_L is going up, and I_Z is going down.

These limit for I_Z will again determine the values of the load we can use.

e. As the load decreases, more current flows through load and less through Zener diode.

From the datasheet of the Zener diode, we need at least $I_{ZK} = 1\ \text{mA}$ though Zener diode for reliable operation.

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	
	Min.	Typ.	Max.		Z_Z @ I_Z (Ω)	Z_{ZK} @ I_{ZK} (Ω)	I_{ZK} (mA)	I_R (μA)	V_R (V)
1N4738A	7.79	8.2	8.61	31	4.5	700	0.5	10	6
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1N4742A	11.4	12	12.6	21	9	700	0.25	5	9.1

Initially (R_L = ∞), the current (with $I_L = 0$) at arbitrary value of 25.5 mA:

$$I_R = I_Z + I_L = 25.5\ \text{mA}$$

As R_L decreases, I_L increase and I_Z decreases. I_Z is minimum when $I_Z = I_{ZK} = 1\ \text{mA}$. This results in the current flows in the load:

$$I_L = I_R - I_Z = 25.5\ \text{mA} - 1\ \text{mA} = 24.5\ \text{mA}$$

As a result, the resistance across the load (taken at V_L = 12 V):

$$R_L = \frac{12\ \text{V}}{24.5\ \text{mA}} = 490\ \Omega$$

Thus, the load resistance can vary between $490\ \Omega \le R_L \le \infty$. Build in some safety margin on the minimum load resistance ($R_L(\text{min})$):

$$R_L(\text{min}) \cong 1\ \text{k}\Omega$$

3. Zener Limiters

Zener diode can be used also for limiting the voltage in the circuit i.e. providing lower and upper thresholds of the operating conditions of the circuit.

Given in the following circuits, the first case will limit the upper threshold of the circuit (V_Z ~ -0.7 V) whereas case 2 will limit the lower threshold (0.7 V ~ V_Z).

The third case limit both the upper and lower thresholds of circuit (+V_Z + 0.7 V ~ -V_Z - 0.7 V).

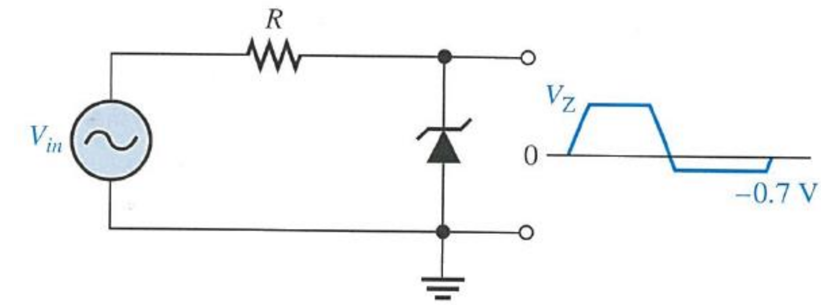


Figure 5: Voltage clamping circuit with Zener diode (case 1).

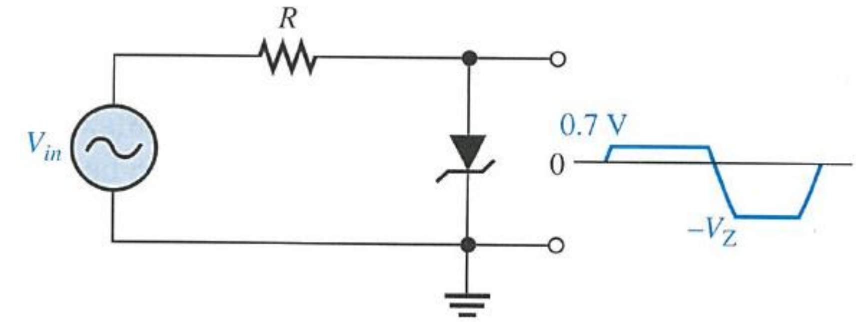


Figure 6: Voltage clamping circuit with Zener diode (case 2).

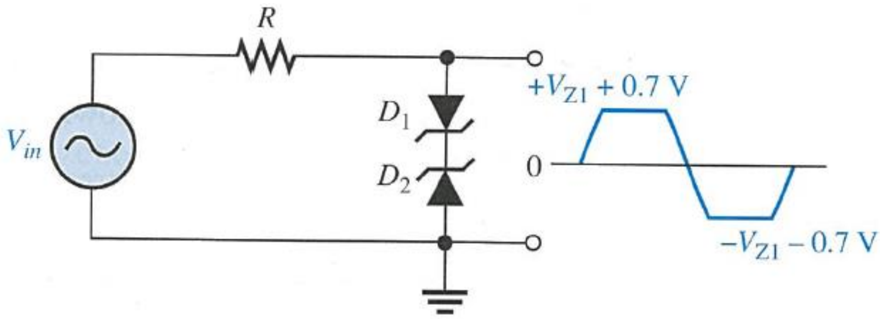


Figure 7: Voltage clamping circuit with Zener diode (case 3).

For the following cases, the thresholds are set at different values than the previous ones. What will the following waveforms look like?

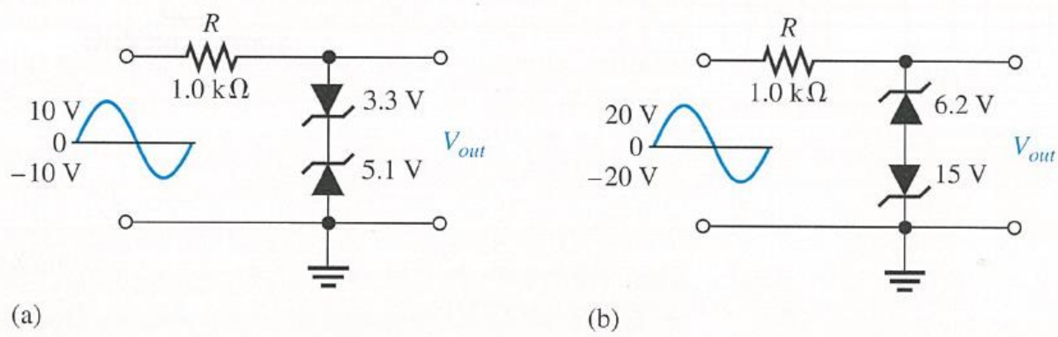


Figure 8: Voltage clamping circuits with Zener diodes.

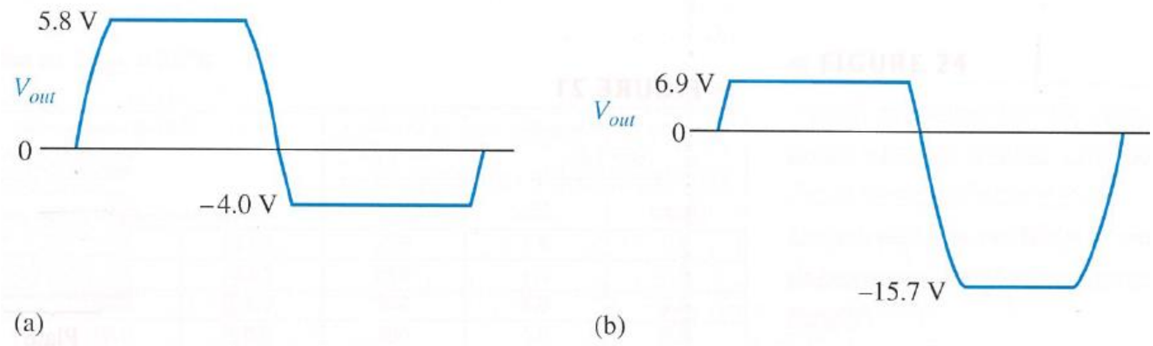


Figure 9: Output waveforms of the voltage clamping circuits.

To end off: real life is always a bit more complicated!

4. Voltage Regulator with Zener Diodes

The last step in our power supply block diagram from previous lecture was a voltage regulation step i.e. we want to keep the output voltage as close as possible to a specified value irrespective of changes in the input voltage or the load.

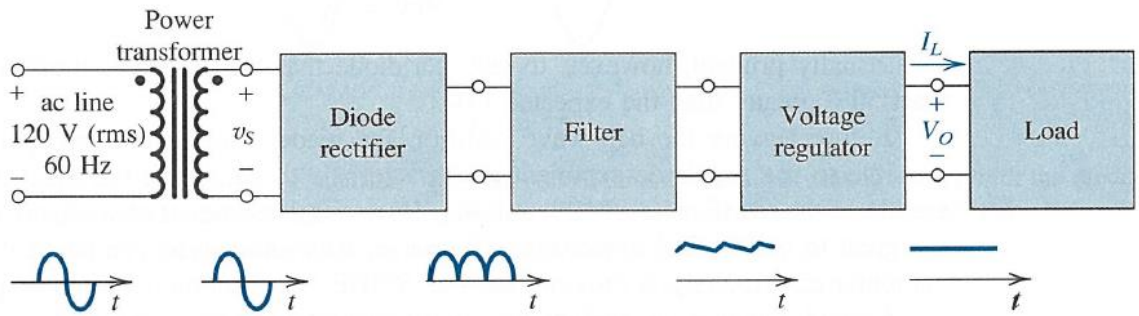


Figure 10: Power supply block diagram

We will now look at different ways to achieve voltage level regulation in a circuit.

4.1. Zener Diodes as Voltage Regulator

Zener diodes are designed and fabricated to provide a specified breakdown voltage. When used in reverse bias, at breakdown, large currents can flow which needs to be limited to avoid damage to the device. Zener diode is typically used as a constant-voltage reference in a circuit, as the breakdown voltage is essentially constant over a range of currents and temperatures.

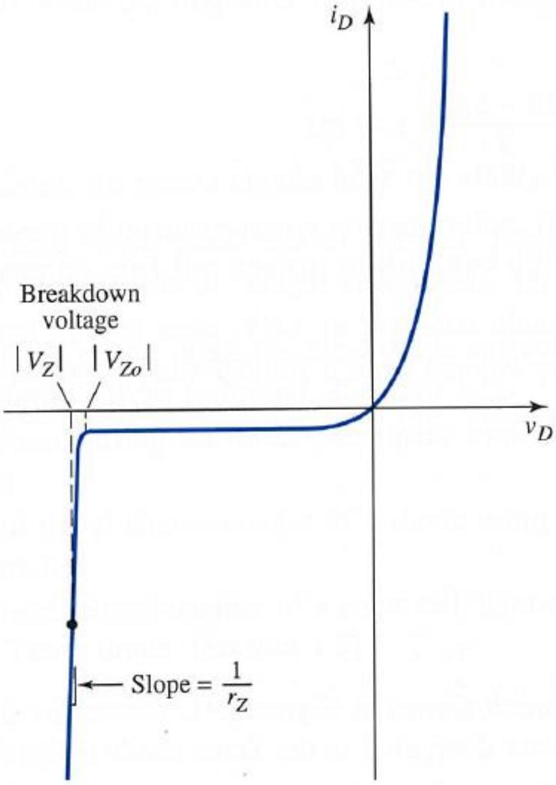


Figure 11: Current-voltage curve plot diagram for a Zener diode.

4.2. Analysing Zener Diode Circuit for Voltage Regulator

For performing analysis of Zener diode circuits, consider the following arrangement of Zener diode.

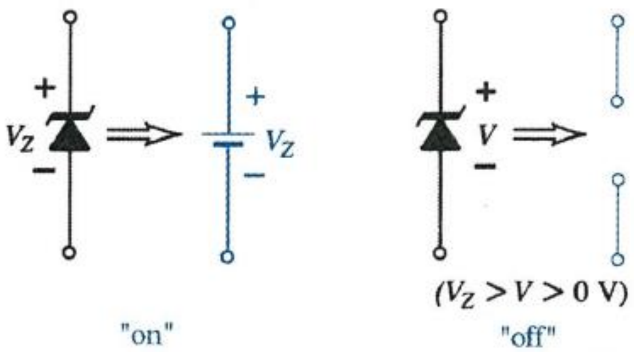


Figure 12: Conduction characteristics of Zener diode.

If the voltage over the diode is $V_Z > V > 0$, the diode is reverse biased, but below its breakthrough voltage i.e. the diode will thus be OFF and look like a normal reverse biased diode (an open circuit).

If the diode is reverse biased to its breakthrough voltage, it will have a voltage drop (the Zener voltage V_Z) over it will also show a very small resistance that can be taken into account in the model.

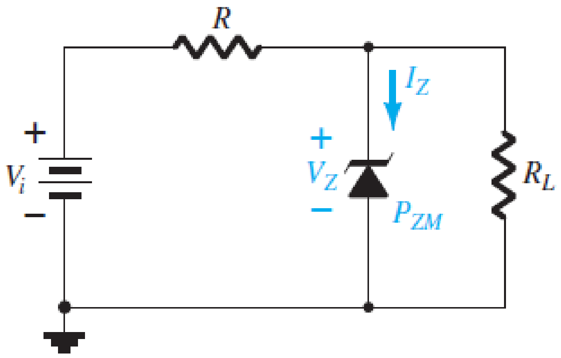


Figure 13: Application of Zener diode in circuit.

Consider the Zener circuit on the above. The applied dc voltage is fixed, as well as the load resistor R_L. The analysis can be done in two steps:

1. Determine the state of the Zener diode by removing it from the calculation of the voltage across the open circuit.

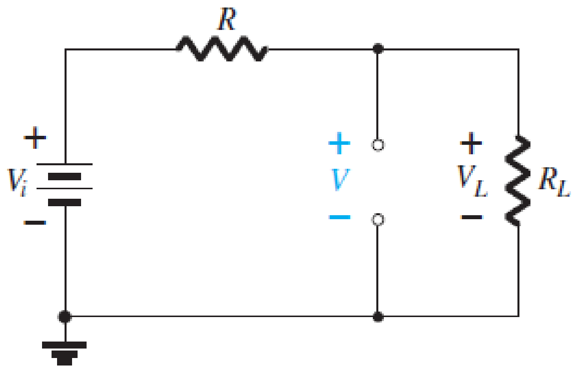


Figure 14: Equivalent circuit of Zener diode when $V < V_Z$.

If $V < V_Z$ then the diode is OFF and can be modelled by an open circuit equivalent.

$$V = V_L = V_i\left(\frac{R_L}{R + R_L}\right)$$

2. Determine the state of the Zener diode by adding voltage source equivalent to the Zener diode rating to the circuit.

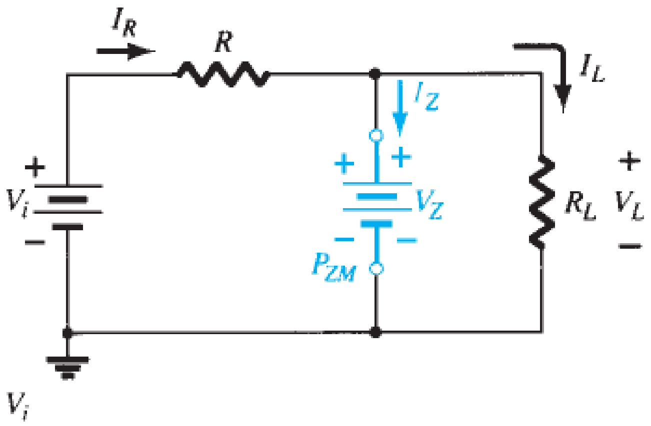


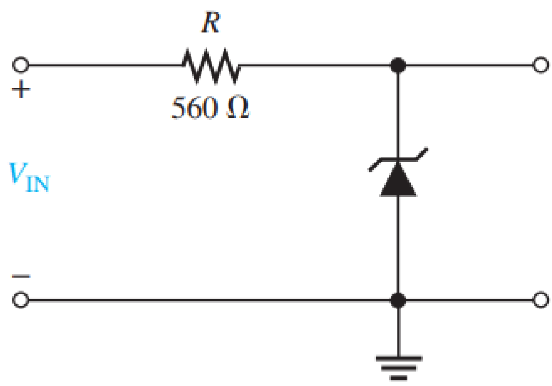
Figure 15: Equivalent circuit of Zener diode when $V > V_Z$.

If $V > V_Z$ the diode is ON the equivalent circuit as on right will result. Thus:

$$V_L = V_Z,\ I_R = I_Z + I_L \text{ and } P_Z = V_Z I_Z$$

Example for Tutorial 4 – Zener Diode as Voltage Regulator

1. When a Zener diode is used in a voltage regulation application, assume an ideal Zener diode with minimum knee current value $(I_{ZK}) = 1.5$ mA and $V_Z = 14$ V.



a. Describe briefly how Zener diode maintain the voltage in the circuit. [2 marks]

b. Determine the minimum input voltage required for regulation to be established in the figure above. [5 marks]

Answer

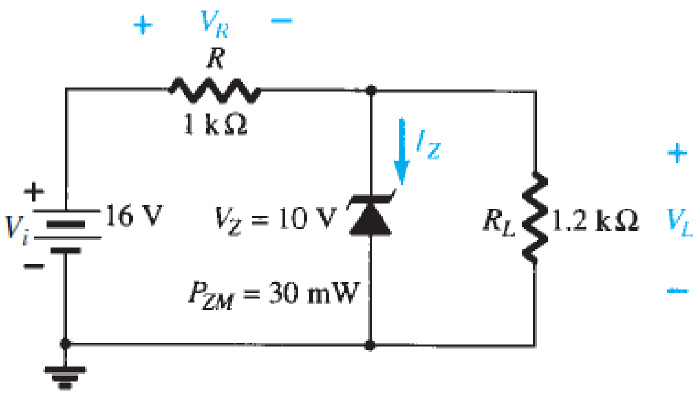
a. If the voltage across it increases, the Zener diode maintains a constant voltage across the load by absorbing the extra current and keeping the load current constant.

b. For the given Zener diode circuit, applying KVL on the circuit, the minimum input voltage is: [2.5]

$$V_{in}(\text{min}) = V_R + V_Z = (I_{zk} \times R) + V_Z$$
$$= (1.5\ \text{mA})(560) + 14 = 14.84\ \text{V}$$

2. For the Zener network as shown in the figure below, perform the following tasks:

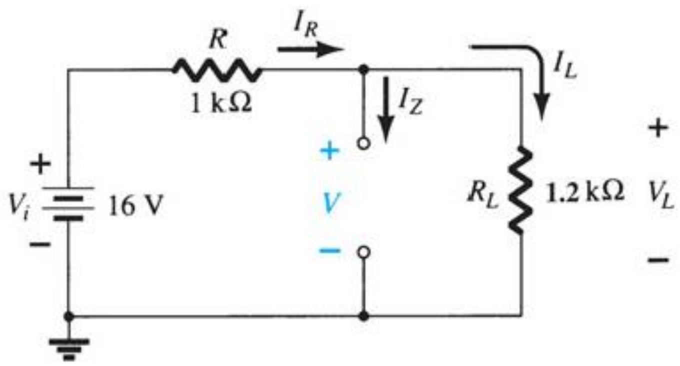
   a. Calculate V_L, V_R, I_Z and P_Z. [8 marks]
   b. Repeat with a load resistor R_L = 3 kΩ. [8 marks]



Answer

a. First, use suggested procedure and remove Zener diode from circuit.

   The following diagram illustrates the equivalent circuit of the given Zener diode application when V < V_Z.



   The circuit above is calculated when the voltage across the Zener diode V = 8.73 V. Thus, V is below the Zener voltage for this diode i.e. 10 V. As a result, the diode is OFF.

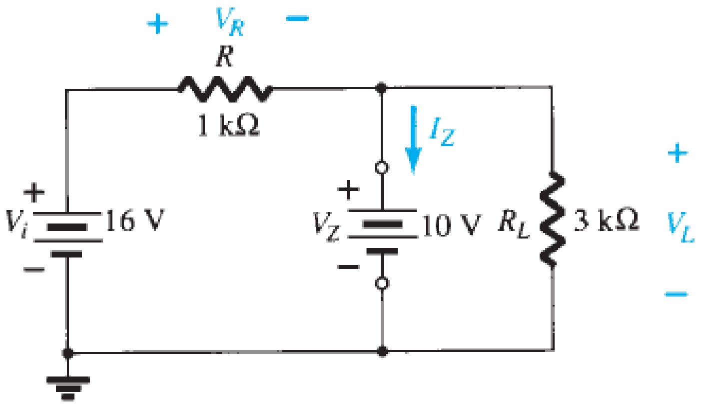
   This results in the voltage across the load resistor is:

$$V_R = V_i - V = 16 - 8.73 = 7.27\ \text{V}$$

And also I_Z = 0 and P_Z = 0.

b. Then, for the second case, we change the load resistor to R_L = 3 kΩ.

The following diagram shows the equivalent circuit of the given Zener diode application when $V > V_Z$.



For the state when diode "removed", the voltage across the load is:

$$V = \left(\frac{R_L}{R + R_L}\right) V_i = \left(\frac{3\text{k}\Omega}{1\text{k}\Omega + 3\text{k}\Omega}\right) 16 \text{ V} = 12 \text{ V}$$

Thus, the diode is ON. If the diode is ON, V_Z = V_L = 10 V so that voltage across the resistor is:

$$V_R = V_i - V_L = 16 - 10 = 6 \text{ V}$$

For the load R_L:

$$I_L = \frac{V_L}{R_L} = \frac{10}{3000} = 3.33 \text{ mA}$$

For the limiting resistor R:

$$I_R = \frac{V_R}{R} = \frac{6}{1000} = 6 \text{ mA}$$

Thus, current through diode is:

$$I_Z = I_R - I_L = 6 \text{ mA} - 3.33 \text{ mA} = 2.67 \text{ mA}$$

As a result, the power dissipated is:

$$P_Z = V_Z I_Z = (10 \text{ V})(2.67 \text{ mA}) = 26.7 \text{ mW}$$

This P_Z is smaller than the P_{ZM} of 30 mW.

5. Integrated Circuit Voltage Regulator

The following diagram shows a voltage regulator integrated circuit i.e. the LM7805. It is a +5 V IC voltage regulator.

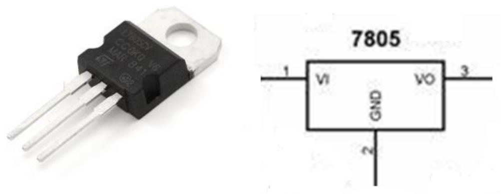


Figure 16: LM 7805 Voltage regulator

The diagram below shows the internal components of the integrated circuit. The features inside enables more complex regulation operations of the voltage in the circuit.

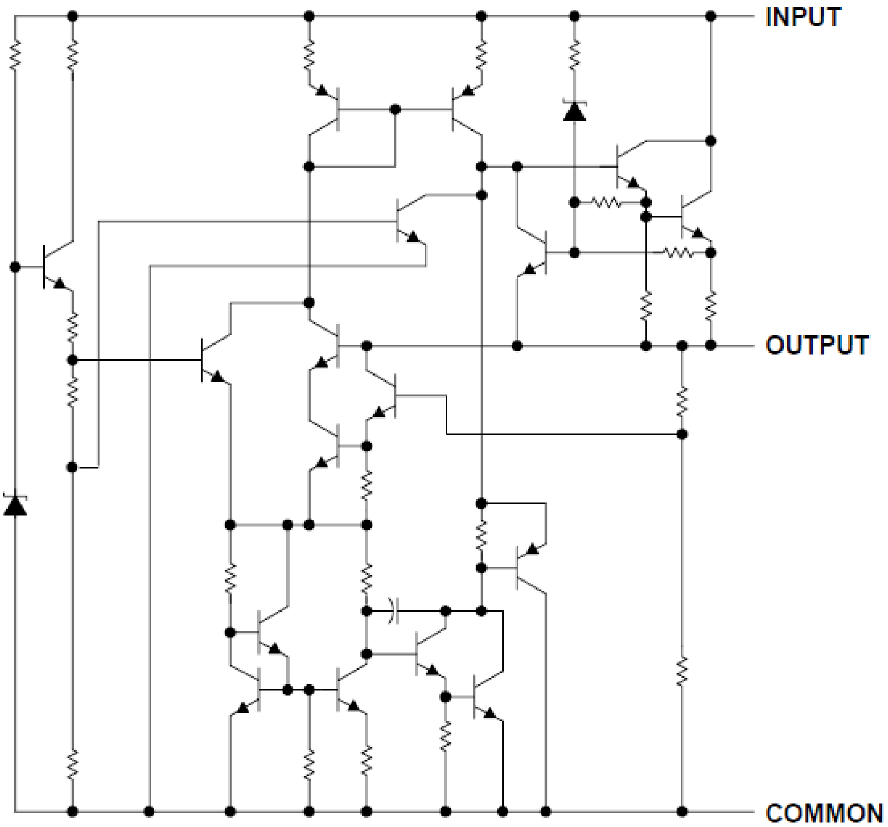


Figure 17: Schematic of the LM7805 (+5 V IC voltage regulator).

Looking into LM7805 functionalities, there a few functionalities required for managing voltage regulation of the circuit i.e. comparing the state of the voltage in the circuit with reference voltage.

There are also other more advance features of the voltage regulator i.e. protecting the condition of the circuit for its safe operation area (SOA) and protecting for harsh thermal condition.

Also in the LM 7805, there is a feature for safe initial starting circuit avoiding a rush of current when the circuit is turned on.

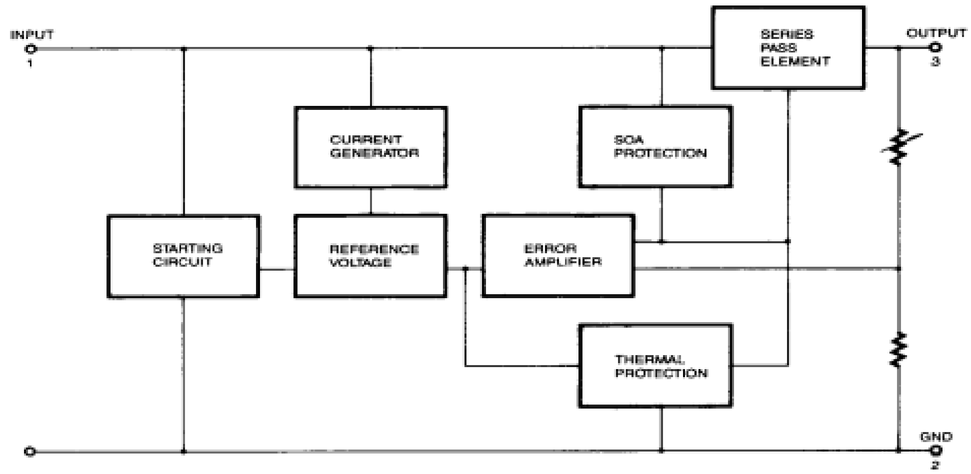


Figure 18: Block diagram of the features of LM7805.

Realising the LM7805 integrated circuit in a power supply application circuit, require you utilise additional components and to set the circuit for required operating condition of the circuit.

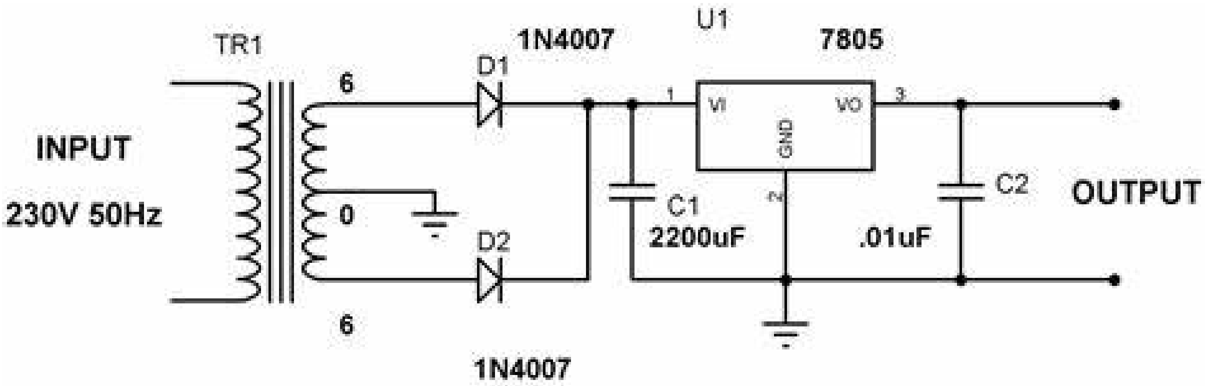


Figure 19: Voltage regulator circuit based on the 7805 IC.

Referring to the circuit given above, it is a voltage regulator circuit based on LM7805. It has a step-down transformer that convert power from 220 V AC to 6 V AC.

Then, there is a centre tap full-wave diode rectifier that provide full-wave rectification to the circuit. It has also an input capacitor to smooth out ripple in the input.

In this voltage regulator circuit, the voltage regulator LM7805 provides +5 V DC in the output. Finally, an output capacitor to smooth out ripple in the output.

Appendix 1 – Datasheet of 1N746A Diode

FAIRCHILD
SEMICONDUCTOR®

Zeners
1N4370A - 1N4372A
1N746A - 1N759A

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

Symbol	Parameter	Value	Units
P_D	Power Dissipation @ TL ≤ 75°C, Lead Length = 3/8"	500	mW
	Derate above 75°C	4.0	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.

Tolerance = 5%

DO-35 Glass case

COLOR BAND DENOTES CATHODE

Electrical Characteristics T_A=25°C unless otherwise noted

Device	V_Z (V) @ I_Z = 20mA (Note 1)			Z_Z (Ω) @ I_Z = 20mA	I_{ZM} (mA) (Note 2)	I_R (µA) @ V_R = 1V	
	Min.	Typ.	Max.			Ta = 25°C	Ta = 125°C
1N4370A	2.28	2.4	2.52	30	150	100	200
1N4371A	2.57	2.7	2.84	30	135	75	150
1N4372A	2.85	3.0	3.15	29	120	50	100
1N746A	3.14	3.3	3.47	28	110	10	30
1N747A	3.42	3.6	3.78	24	100	10	30
1N748A	3.71	3.9	4.10	23	95	10	30
1N749A	4.09	4.3	4.52	22	85	2	30
1N750A	4.47	4.7	4.94	19	75	2	30
1N751A	4.85	5.1	5.36	17	70	1	20
1N752A	5.32	5.6	5.88	11	65	1	20
1N753A	5.89	6.2	6.51	7	60	0.1	20
1N754A	6.46	6.8	7.14	5	55	0.1	20
1N755A	7.13	7.5	7.88	6	50	0.1	20
1N756A	7.79	8.2	8.61	8	45	0.1	20
1N757A	8.65	9.1	9.56	10	40	0.1	20
1N758A	9.50	10	10.5	17	35	0.1	20
1N759A	11.40	12	12.6	30	30	0.1	20
V_F Forward Voltage = 1.5V Max @ I_F = 200mA							

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. Maximum Zener Current Ratings (I_{ZM})
   The maximum current handling capability on a worst case basis is limited by the actual zener voltage at the operation point and the power derating curve.

Appendix 2 – Datasheet of 1N4740A Diode

FAIRCHILD
SEMICONDUCTOR®

June 2007

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.

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	Max. Zener Impedance			Leakage Current	
	Min.	Typ.	Max.	I_Z (mA)	Z_Z @ I_Z (Ω)	Z_{ZK} @ I_{ZK} (Ω)	I_{ZK} (mA)	I_R (μA)	V_R (V)
1N4728A	3.315	3.3	3.465	76	10	400	1	100	1
1N4729A	3.42	3.6	3.78	69	10	400	1	100	1
1N4730A	3.705	3.9	4.095	64	9	400	1	50	1
1N4731A	4.085	4.3	4.515	58	9	400	1	10	1
1N4732A	4.465	4.7	4.935	53	8	500	1	10	1
1N4733A	4.845	5.1	5.355	49	7	550	1	10	1
1N4734A	5.32	5.6	5.88	45	5	600	1	10	2
1N4735A	5.89	6.2	6.51	41	2	700	1	10	3
1N4736A	6.46	6.8	7.14	37	3.5	700	1	10	4
1N4737A	7.125	7.5	7.875	34	4	700	0.5	10	5
1N4738A	7.79	8.2	8.61	31	4.5	700	0.5	10	6
1N4739A	8.645	9.1	9.555	28	5	700	0.5	10	7
1N4740A	9.5	10	10.5	25	7	700	0.25	10	7.6
1N4741A	10.45	11	11.55	23	8	700	0.25	5	8.4
1N4742A	11.4	12	12.6	21	9	700	0.25	5	9.1