Analog Electronics

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1st **semester**

Chapter 3
Special-Purpose Diodes

Lec. 6

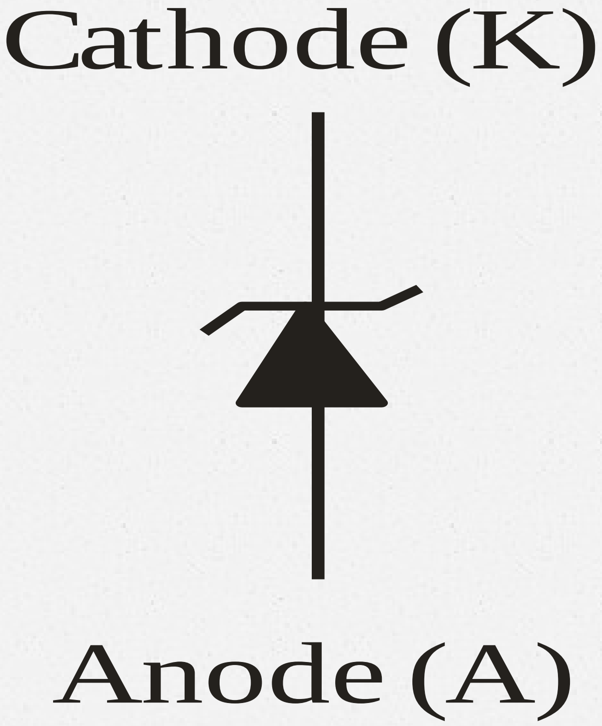
The Zener Diode

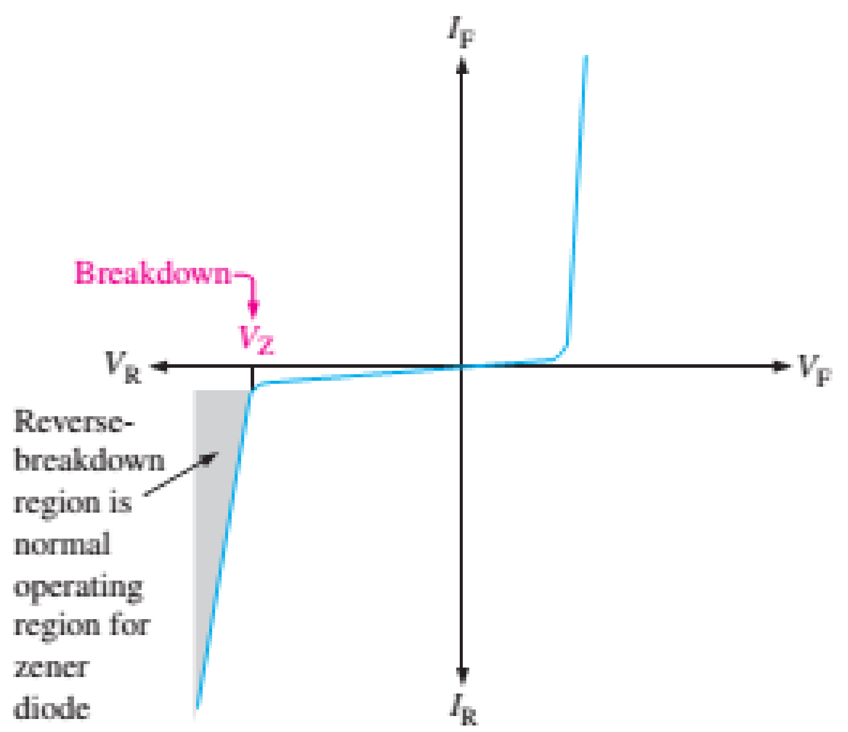
A Zener diode **is** a **silicon pn junction device** designed for **operation in the reverse-breakdown region**.

When a diode **reaches reverse breakdown**, its **voltage remains almost constant even though the current changes drastically**, and this is **key** to the zener diode operation.

A major **application** for zener diodes is a voltage regulator for **providing** stable reference voltages for **power supplies, voltmeters,** and **other** instruments.

The symbol for a Zener diode is shown in Figure 1.





Forward Bias

Zener diodes with **breakdown voltages** of **less than approximately 5V operate** in zener breakdown.

Those with breakdown **voltages greater than approximately 5V** operate mostly in **avalanche breakdown**. Both types are called zener diodes.

Zener has **breakdown voltages** from **less than 1V to more than 250V**.

As the **reverse voltage (V_R) increases**, the **reverse current (I_R) remains** extremely **small up to the knee of the curve**.

Reverse current is also **called** zener current (I_z).

At the **knee point,** the **breakdown effect begins**, and the **internal zener resistance (Z_Z) decreases**.

The **reverse current increases rapidly**. The **zener breakdown (V_Z) voltage** remains nearly **constant**.

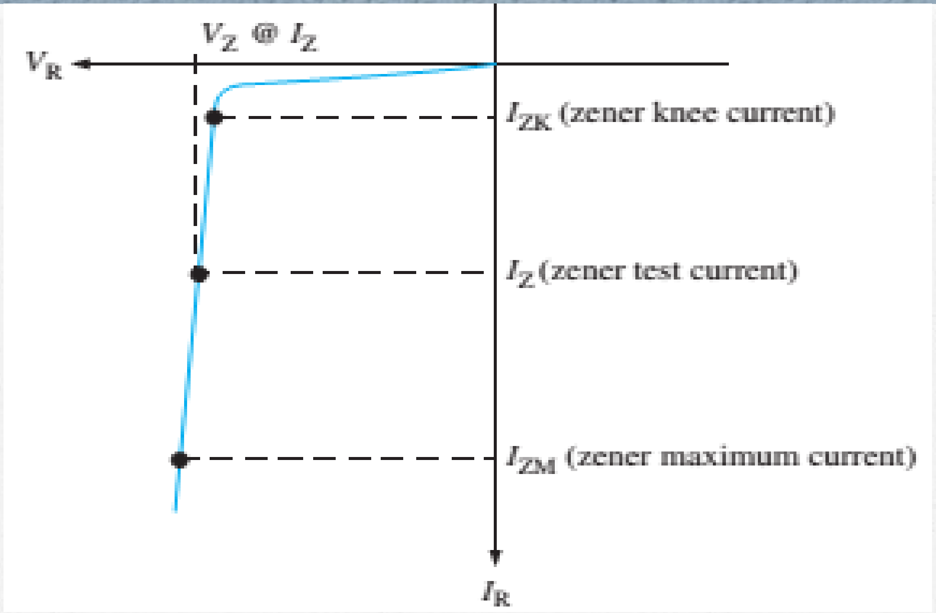


Figure 3: Reverse characteristic of a zener diode.

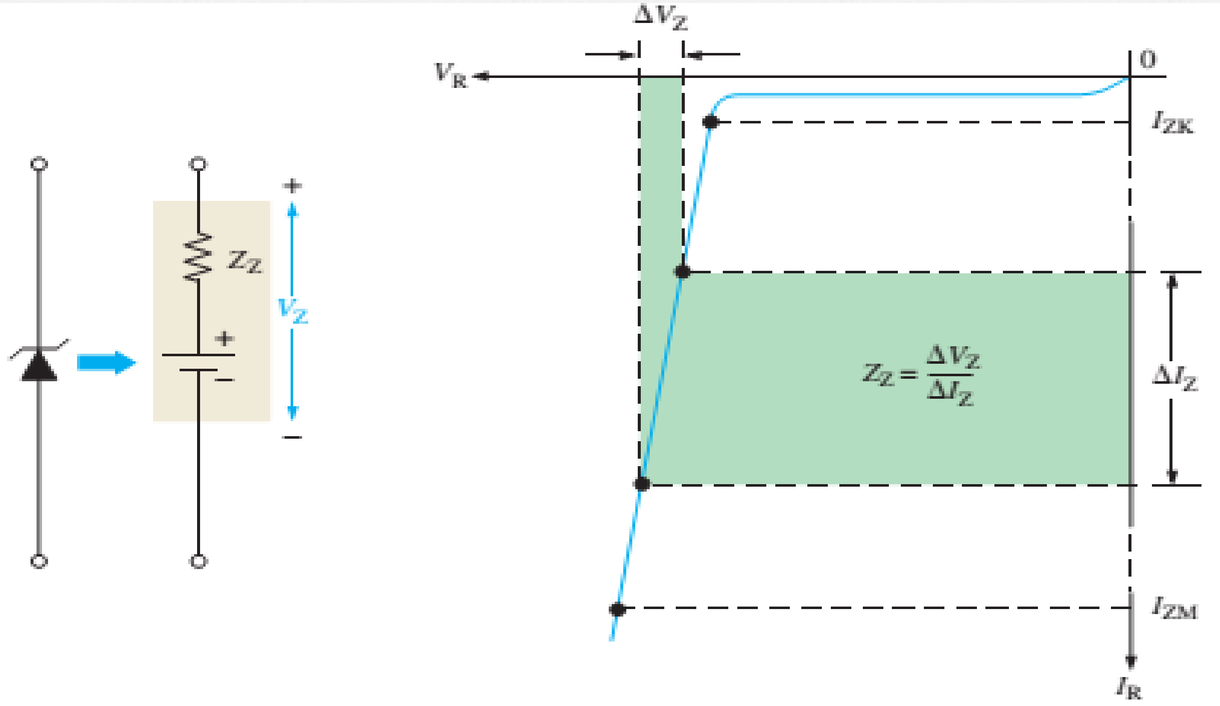
V_Z is usually specified at **a value of the zener current** known as **the test current.**

The **zener impedance**, Z_Z, is the **ratio** of a **change in voltage** in the **breakdown region to the corresponding change in the current**:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

The **zener** **impedance**, Z_Z, is the **ratio** of a **change in voltage** in the **breakdown region to the corresponding change in the current**:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$



(a) Practical model (b) Characteristic curve. The slope is exaggerated for illustration.

Example 1: What is the zener impedance if the zener diode voltage changes from 4.79 V to 4.94 V when the current changes from 5.00 mA to 10.0 mA? **HW**

Zener Diode Applications

Zener Regulation with a Variable Input Voltage

The zener diode can be used as a **voltage regulator for providing stable reference voltages,** as shown in Figure 5.

The **ability** to **keep reverse voltage constant across** its terminal is the **key feature of the zener diode**. It maintains **constant voltage** over a **range of reverse current values**.

A **minimum reverse current I_{ZK}** must be maintained to **keep the diode** in **regulation mode**.

Voltage decreases drastically **if** the **current is reduced below the knee of the curve**.

Above I_{ZM}, max current, the **zener may get damaged permanently**.

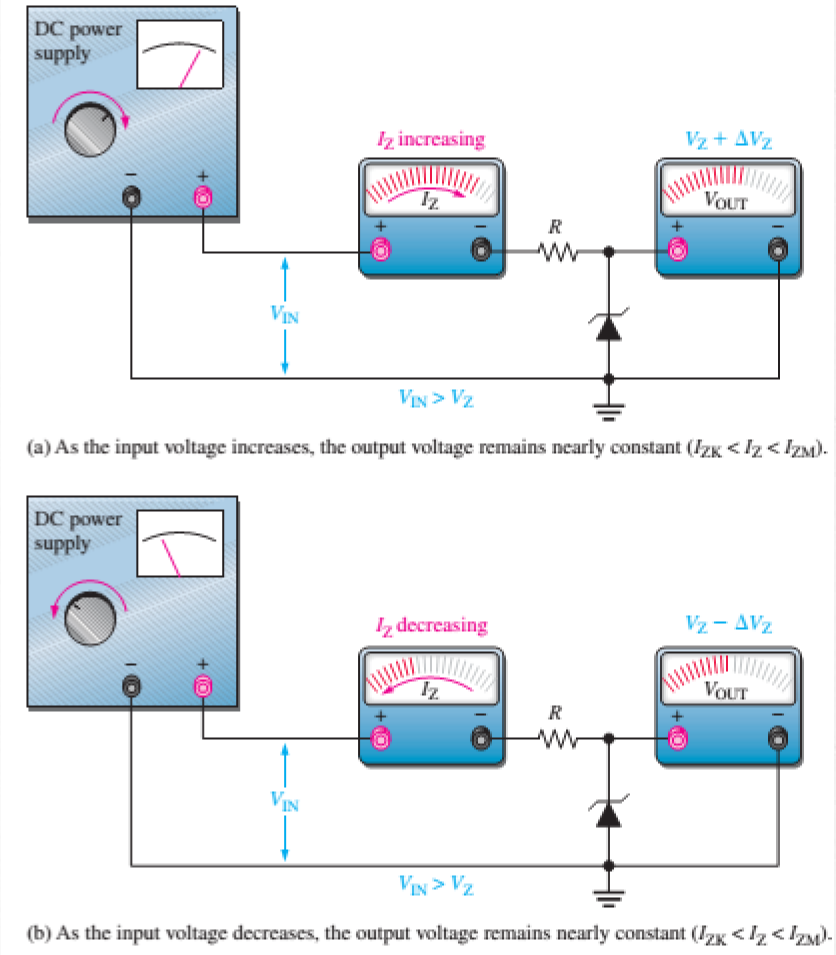
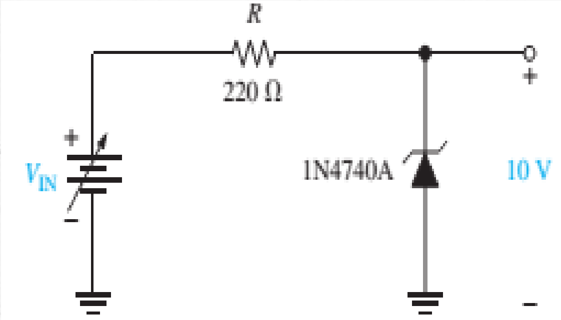


Figure 5: Zener regulation of a varying input voltage.

To illustrate **regulation**, let us **use** the **ideal model of the 1N4740A zener diode** (**ignoring** the zener resistance) in the circuit of Figure 6.

- Ideal model of IN4047A
- I_{ZK} = 0.25mA
- V_Z = 10V
- P_D(max) = 1W



For the minimum zener current, the voltage across the 220Ω resistor is

$$V_R = I_{ZK}R = (0.25\text{ mA})(220\Omega) = 55\text{mV},$$

Since $V_{IN} = V_R + V_Z$,

$$V_{IN(min)} = V_R + V_Z = 55\text{mV} + 10\text{V} = 10.055\text{V}$$

For the maximum zener current, the voltage across the 220Ω resistor is

$$V_R = I_{ZM}R = (100\text{ mA})(220\Omega) = 22\text{V}$$

Therefore, $V_{IN(max)} = 22\text{V} + 10\text{V} = 32\text{V}$

This shows that this **zener diode can ideally regulate an input voltage from 10.055 to 32V** and **maintain an approximate 10V output**.