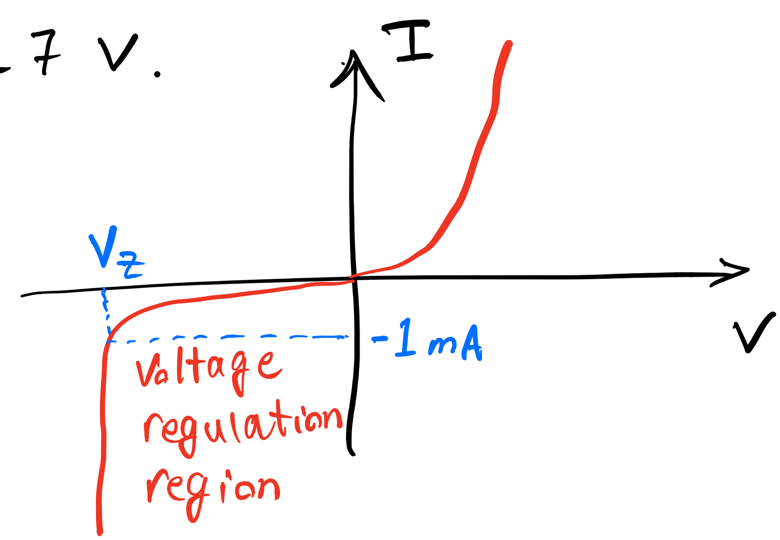
Zener diodes

There are several other types of diodes beside the junction diode. As the reverse voltage increases the diode can avalanche-breakdown (Zener breakdown) This causes an increase in current in the reverse direction. Zener breakdown occurs when the electric field near the junction becomes large enough to excite valence electrons directly into the conduction band.

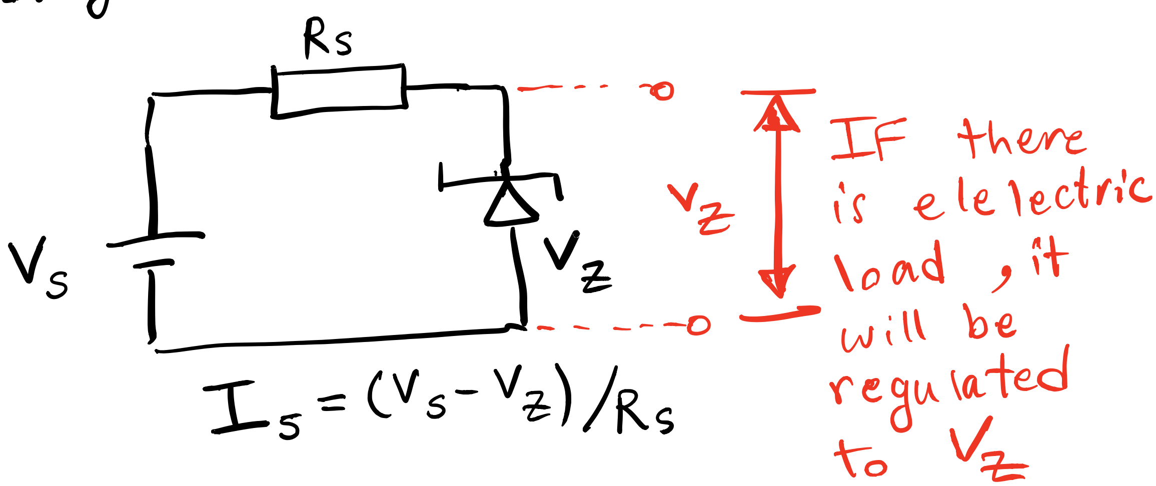
Avalanche breakdown is when the minority carriers are accelerated in the electric field near the junction to sufficient energies that they can excite valence electrons through collisions. Therefore the zener diode is considered as a silicon diode with optimized operation in the breakdown region (2-200V).

The figure below shows the current-voltage characteristic of a zener diode, its schematic symbol and equivalent circuit model in the reverse-bias direction. The best zener diodes usually have a breakdown voltage V_z of 6-7 V.



symbol

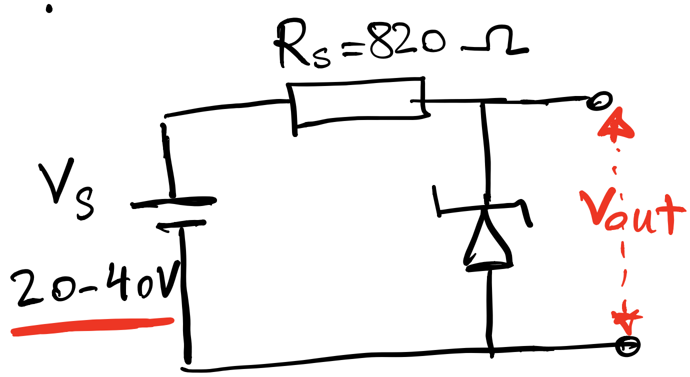
There are several uses of zener diode, the main use is as a regulator for maintaining a predefined level of voltage.



$$I_s = (V_s - V_z)/R_s$$

Example

A zener has breakdown voltage $V_z = 10V$, what is the maximum and minimum current passing through the diode?



$$V_s = I_s R_s + V_Z$$

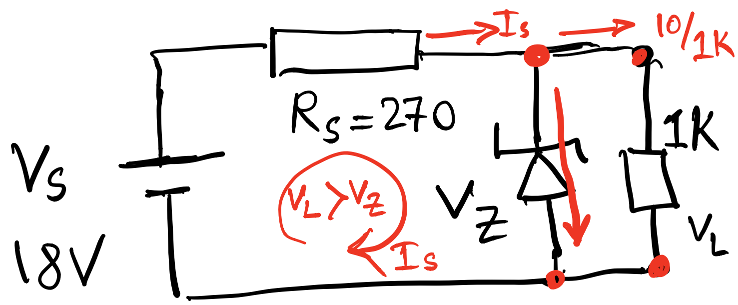
$$I_s = \frac{(V_s - V_Z)}{R_s}$$

$$I_{max} = \frac{(40-10)}{820} = 36 \text{ mA}$$

$$I_{min} = \frac{(20-10)}{820} = 12 \text{ mA}$$

Example

If the zener is operating in the breakdown region, what is its current when open mode.



$$I_L = \frac{18}{1K + 270} = 14.2 \text{ mA} \qquad V_Z > V_L$$

$$V_L = 14.2 \text{ mA} \times 1K\Omega = 14.2 V$$

voltage is not reaching the zener breakdown voltage (for example $V_Z > 14.2$)

when $V_L > V_Z$, then zener operating in breakdown

$$I_s = \frac{18-10}{270} - \frac{10}{1K} = 19.6 \text{ mA}$$

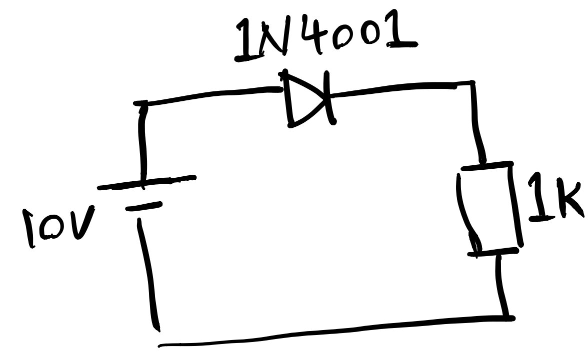
Light Emitting diodes

A light-emitting diode (LED) is a semicanductor device that emits incaherent narrow-spectrum light when electrically biased in the forward direction of the p-n junction. The calour of the emitted light depends on the campositian and canditian of the semicanducting material used, and can be infrared, visible or near ultraviolet.

LED symbol

Example

Calculate the load current, load voltage, load power, diode power and total power in the circuit.



(a) Ideal-diode approximation

(b) carner moder (or called second approximation)

(c) real moder (or called third approximation where the 1N 4001 has a bulk resistance of 0.23 Ω)

a) <u>Ideal- diode approximation:</u>

$V_d = 0$, $I = \frac{10}{1K\Omega} = 10 \, mA$

$$V_{load} = 10 \, V$$

$P_{Load} = 10 \, mA \times 10V = 100 \, mW$

$P_{total} = P_{Load} + P_{Diode} = 100 \, mW$

↓

No power in diode (no bulk resistance and no voltage drop in ideal model)

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b) second approximation:

$V_d = 0.7$ Diode voltage drop

$$I = \frac{10 - 0.7}{1 K\Omega} = 9.3 \, mA$$

$V_{load} = 10 - 0.7 = 9.3V$

$P_{Load} = 9.3\ mA \times 9.3\ V = 86.49\ mW$

$P_{Total} = 9.3mA \times 10\ V = 93\ mW$

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c) Third approximation

$V_d = 0.7$ $R_B = 0.23$ diode bulk resistance

$$I = \frac{10 - 0.7}{1K + 0.23} = 9.298\ mA$$

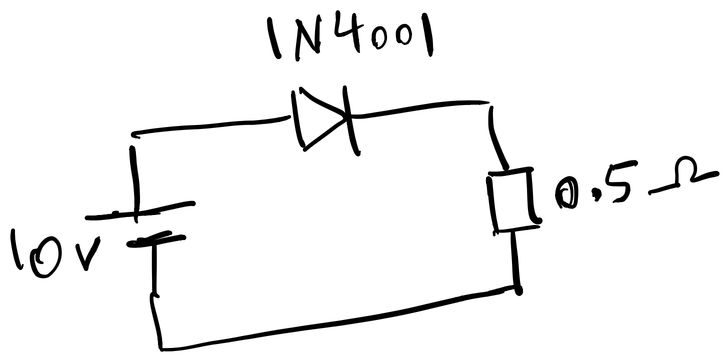
$V_{load} = 9.298\ mA \times 1K\Omega = 9.298V$

$P_{load} = 9.298\ mA \times 9.298\ V = 86.45\ mW$

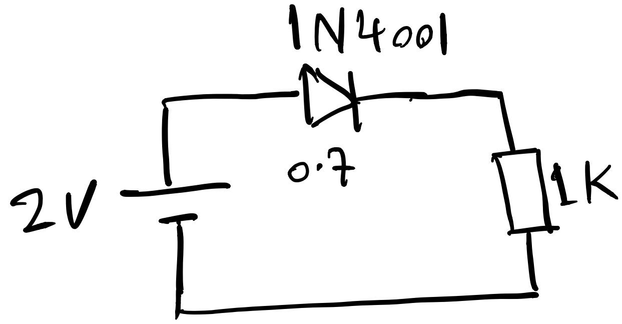
$P_{total} = 9.298 \times 10V = 92.98\ mW$

Example

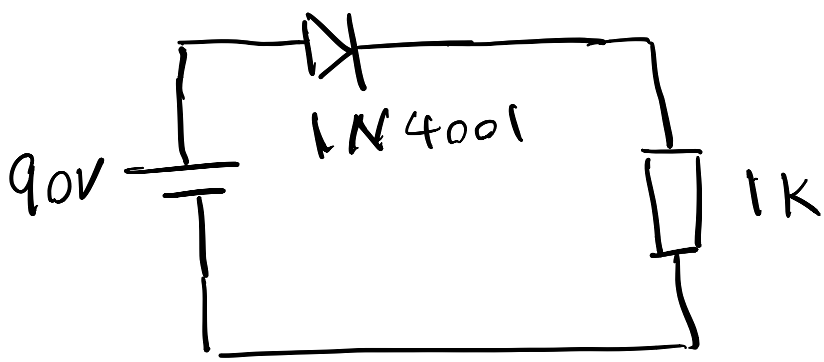
which approximation would you use in the circuit below if the bulk resistance of the diode is 0.23 Ω? why?



use real model because 0.23 Ω and is not far from 0.5 Ω (so we cannot ignore it)



cornen moder
(or 2nd approx.)
since V_S is
small and 0.7
Can not be ignared

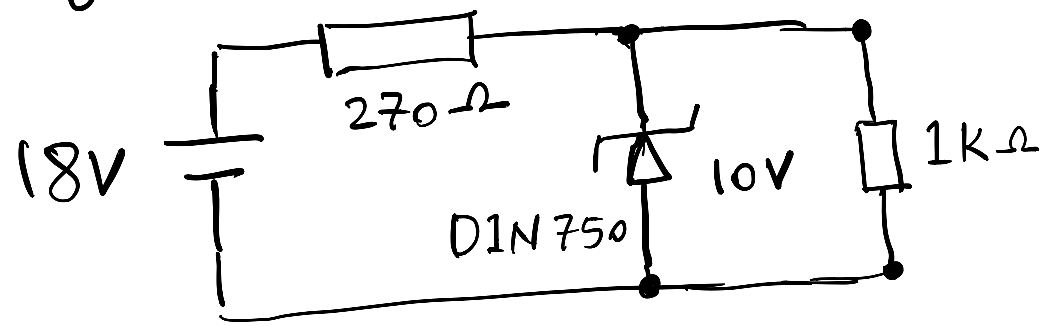


Ideal model
since load
is large
in camparison
to 0.23

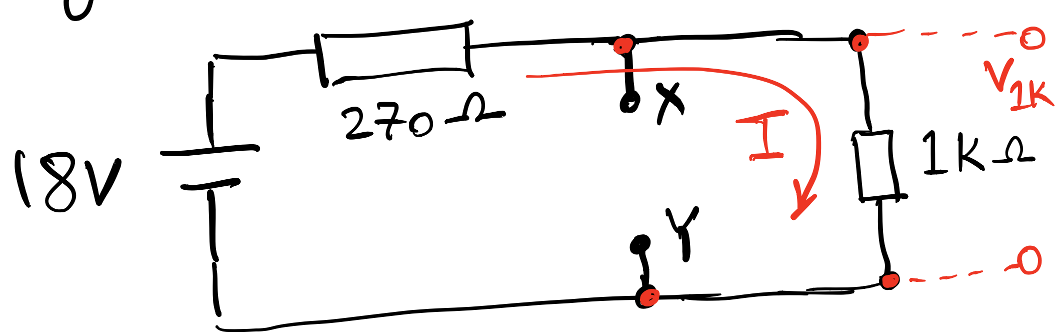
and V_S is
large in comparison
to 0.7.

Example

Is the zener diode in the circuit operating in the breakdown region?



work out the voltage between XY



IF it is more than 10V, then zener will regulate the voltage (Breakdown)

$V_{xy} = 18 - V_R$

$I = \frac{18}{270+1000} = 0.0142\ A$

$V_{1K\Omega} = 0.0142 \times 1000 = 14.2V$

$V_{xy} = 14.2 > 10 \Rightarrow$ Breakdawn

Zener will regulate voltage and operating in the breakdown region.