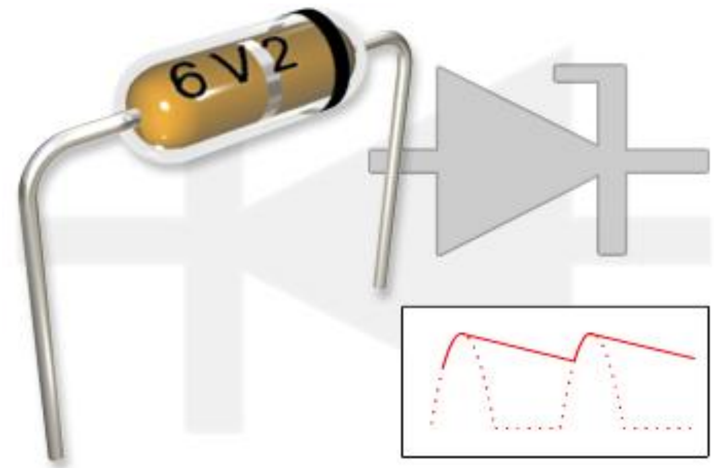
Diode Characteristics and Applications



Topics covered in this presentation:

- Diode Characteristics
- Diode Clamp
- Protecting Against Back-EMF
- Half-Wave Rectifier
- The Zener Diode

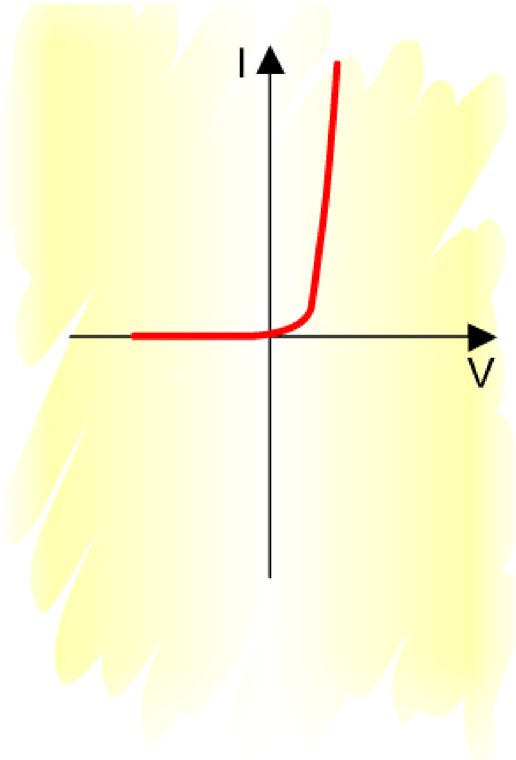
Diode Characteristics

A diode is a semiconductor device that will conduct well in one direction, but stop current flow in the other.

The I-V characteristic curve for a diode shows how the current flowing in a diode is dependent upon the voltage that is applied across it.

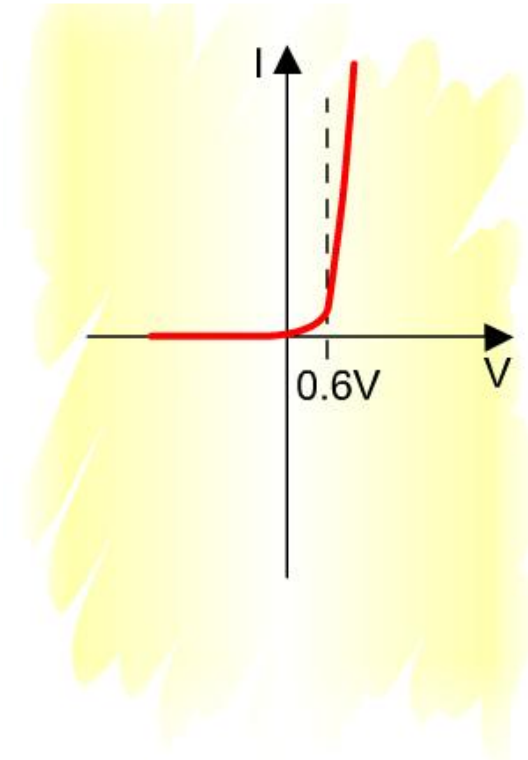
When forward biased, the diode will conduct well and allow a current to pass.

When reverse biased, the diode does not conduct and will stop current flowing.



Diode Characteristics

By examining the I-V characteristic curve, it can be seen that the diode doesn't fully conduct straight away when a forward biased voltage is applied across it.



Before a diode can fully conduct, the depletion layer must be removed by applying a voltage across the diode.

For a silicon diode, typically 0.6V must be applied across the diode before it will conduct.

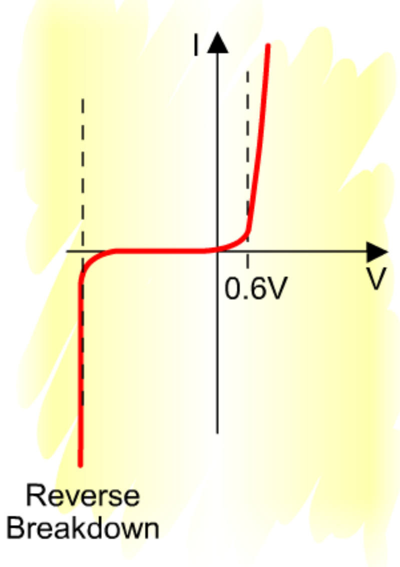
Diode Characteristics

When a diode is reverse biased, a very small current will flow, typically only a few microamps.

However, if the reverse bias voltage is sufficiently large, the current will suddenly rapidly increase. At this point, a large number of the outer electrons that were strongly bonded together, gain enough energy to break free.

This point is called the **reverse breakdown point**. It is also called the **avalanche voltage**.

The value of the avalanche voltage depends on how the diode was manufactured. To prevent damage, a diode must be selected so that the reverse voltage never exceeds this value.



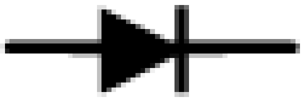
Diode Datasheet

Some of the criteria, found on the product data sheet, to consider when selecting a diode.

- Forward voltage drop
- Maximum forward current
- Reverse current
- Reverse breakdown voltage

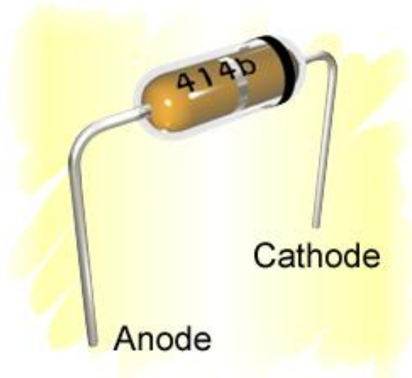
Diode Symbol

A diode is represented by the following symbol.

anode  cathode

The diode will be forward biased when the anode is positive with respect to the cathode.

The cathode on a diode is often marked as shown.



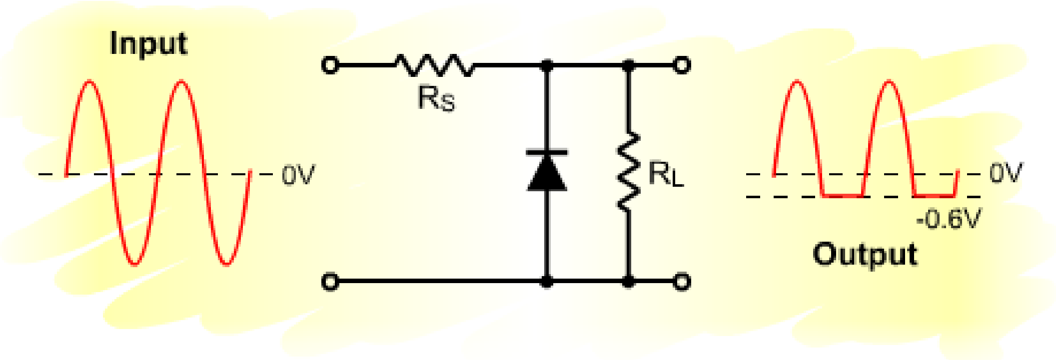
Diode Clamps

Some circuits are designed to receive only positive or negative input voltages, but there may be a possibility of an occasional voltage spike of the opposite polarity. A diode can be used as a **clamp** on the input of the circuit to protect against the high unwanted voltage.

To protect against negative voltages, the diode is connected in reverse bias across the output.

For a positive voltage the diode will not affect the normal operation of the circuit.

When a negative voltage is applied, the negative voltage across the diode, and hence the output, will be limited to the forward voltage drop of the diode.



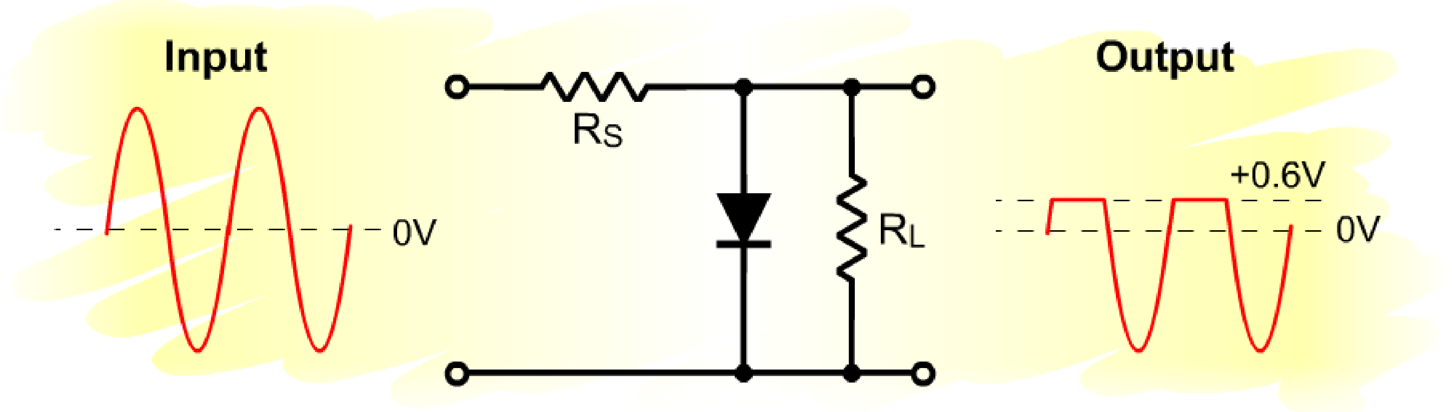
Diode Clamps

To protect against positive voltages, the diode is connected in the opposite direction from the previous example.

For a negative voltage the diode will not affect the normal operation of the circuit.

When a positive voltage is applied, the voltage across the diode, and hence the output, will be limited to the forward voltage drop of the diode.

For a silicon diode, the forward voltage drop is approximately 0.6V.



Diode Clamps

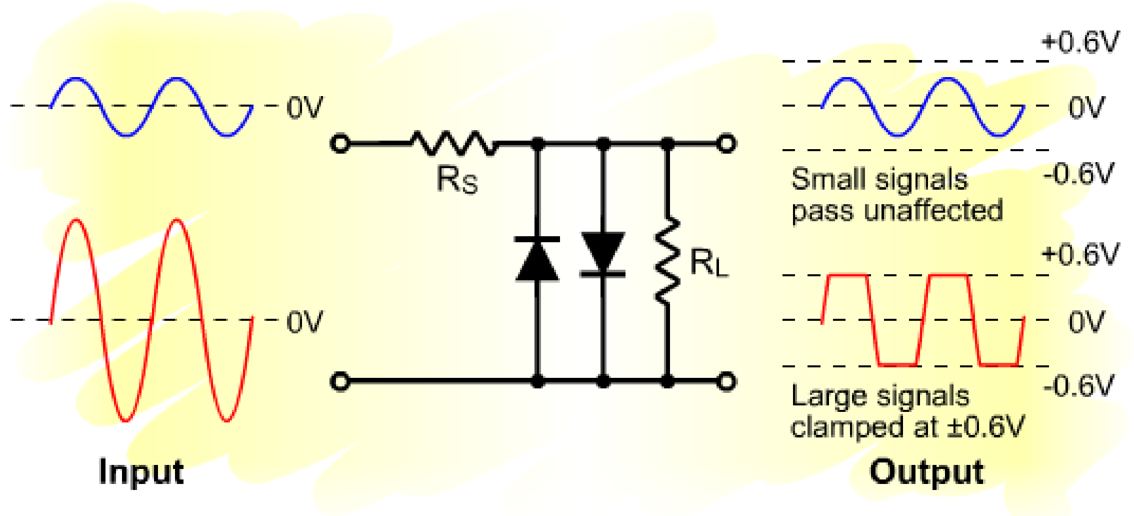
Two diodes, connected across a load in parallel, and biased in opposite directions will limit the voltage to the forward voltage drop in both directions.

Two silicon diodes connected like this will limit the voltage to ±0.6V.

If two diodes are used in each parallel branch, the voltage will be limited to ±1.2V.

Using diodes like this can be used in circuits to protect against voltage overload.

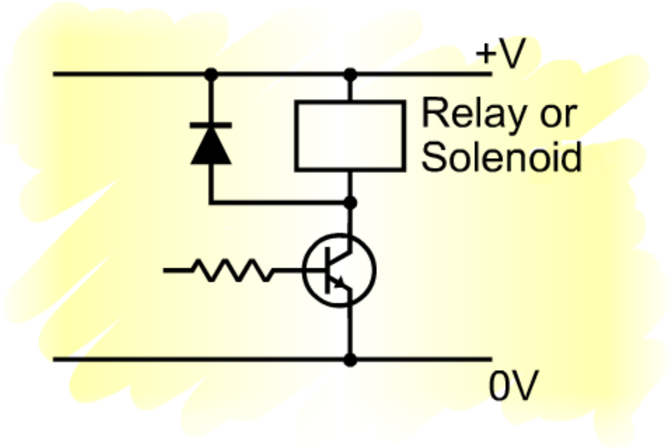
As the unwanted voltage is clipped off, this technique is also known as **clipping**.



Using a Diode to Protect Against Back-EMF

Diodes are often used to protect against the Back-EMF generated in a coil. For example, the coil in a relay.

This can be achieved by connecting a diode in reverse bias across the coil that creates the Back-EMF.



In normal operation the diode will block current, so will not affect the operation of the circuit.

When the relay is switched off, a large Back-EMF is generated. The diode provides a path for the large current caused by the Back-EMF to flow back round into the coil rather than damaging the transistor.

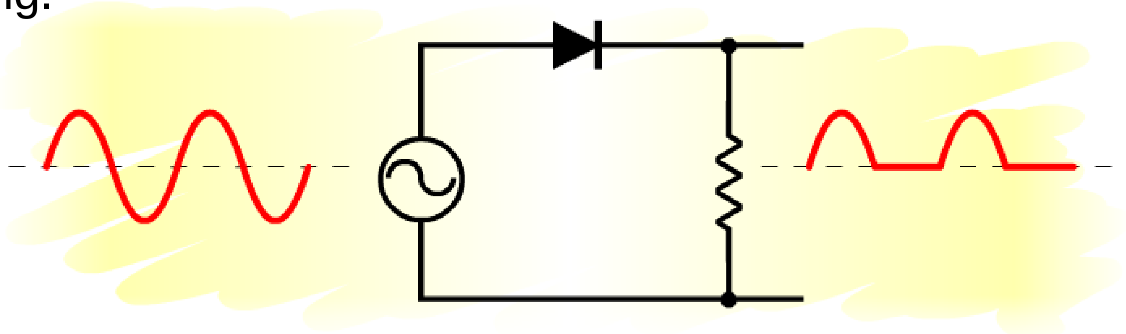
Half-Wave Rectifier

Many electronic circuits require a DC supply to operate, but sometimes they are powered from an AC power supply. The AC supply is therefore converted into a DC supply using a process called **rectification**.

A diode will only allow current to flow in one direction, and so can be used to provide a DC supply.

During the positive half-cycle of the AC input the diode will conduct normally, allowing current to flow.

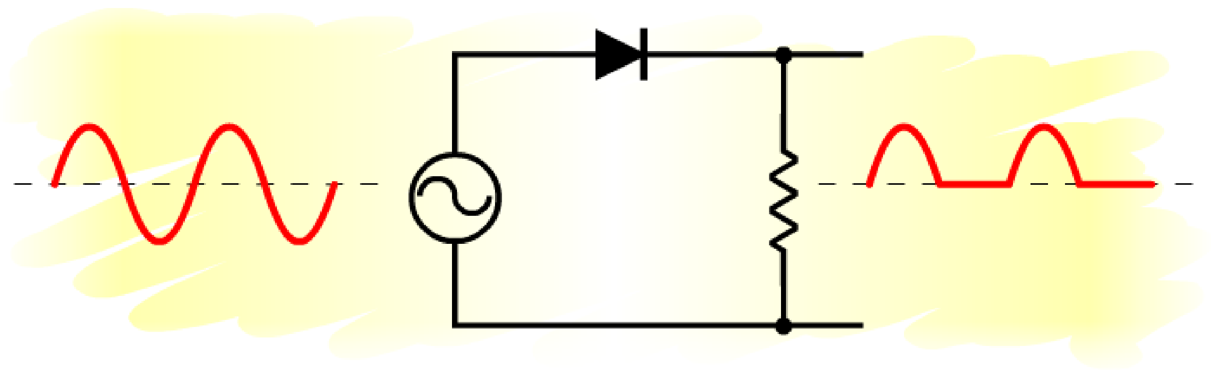
For the negative half-cycles of the AC input, the diode will stop the current flowing.



Half-Wave Rectifier

The output from this simple rectifier will only be the positive half-cycles of the input waveform, and so provides a DC supply.

However, the output voltage will not be very smooth because of the ripples in the output waveform. The **ripple voltage** is the difference between the maximum and minimum voltage at the output.



Improved Half-Wave Rectifier

To smooth out the ripples at the output, a capacitor can be connected across the output of the half-wave rectifier.

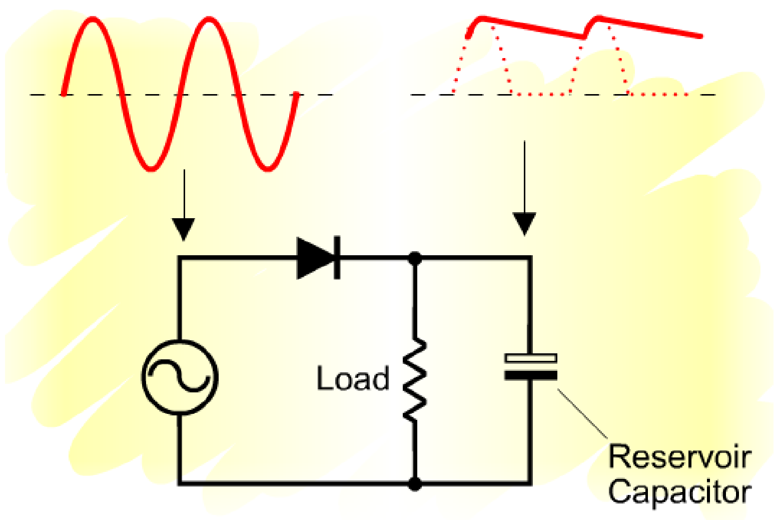
During the positive half-cycles the capacitor will charge up.

Then during each negative half-cycle, when the diode is not conducting, the capacitor discharges very slightly to supply a current to the load.

When the diode conducts, the charge on the capacitor is "topped-up".

The output voltage will not be totally smooth, but the ripple voltage will be significantly reduced.

The capacitor used in this circuit is known as a **reservoir** capacitor with a typical value of 200μF.



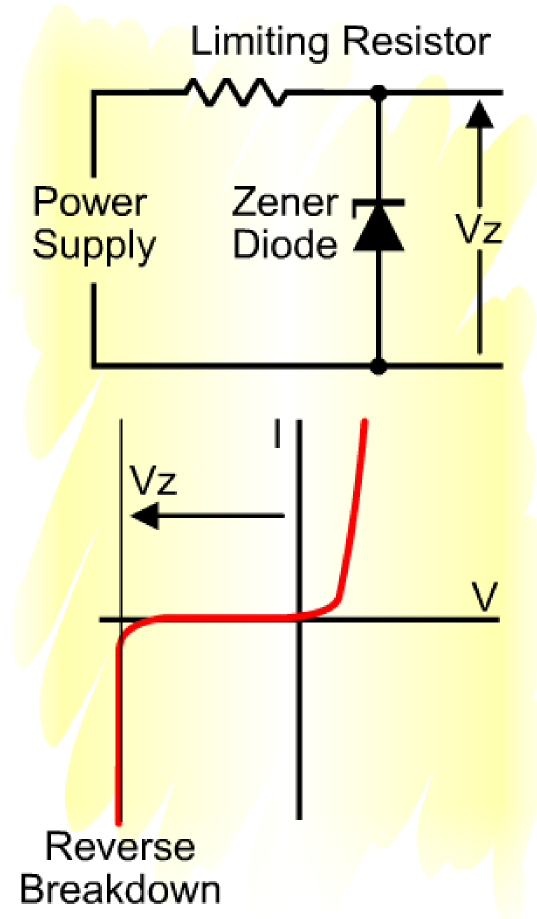
Zener Diode

A **zener diode** is a special type of diode that can be used to regulate a voltage.

The symbol for a zener diode has a bent bar to indicate the cathode.

A zener diode is always operated in reverse bias, so the characteristic curve only shows the reverse characteristic.

Unlike a standard diode, a zener diode is operated in reverse breakdown mode, with current flowing from cathode to anode.

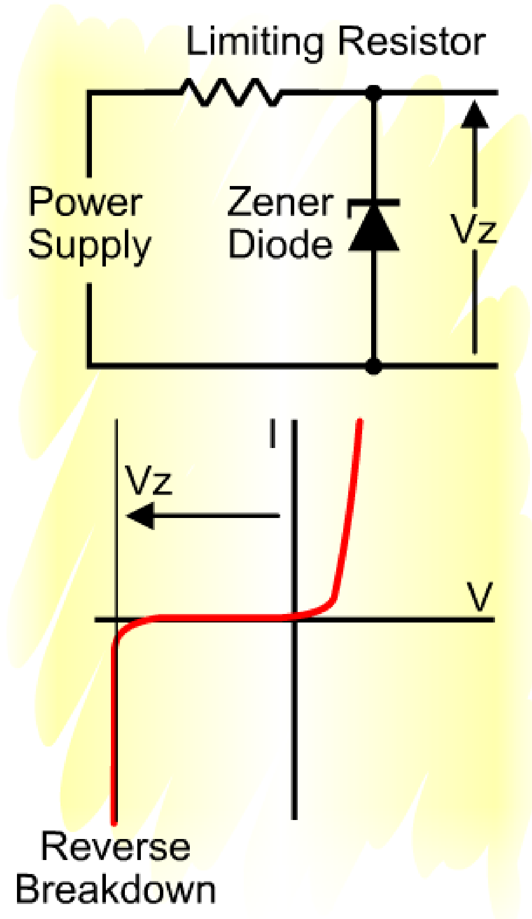


Zener Diode

As long as the maximum rated current is not exceeded, the voltage, V_Z, across the zener diode will be constant, within an error range for all current values.

A series resistor is required to limit the current and prevent damage to the zener diode.

A zener diode has a maximum power rating. To keep within this power rating a resistor is always connected in series with the zener diode.



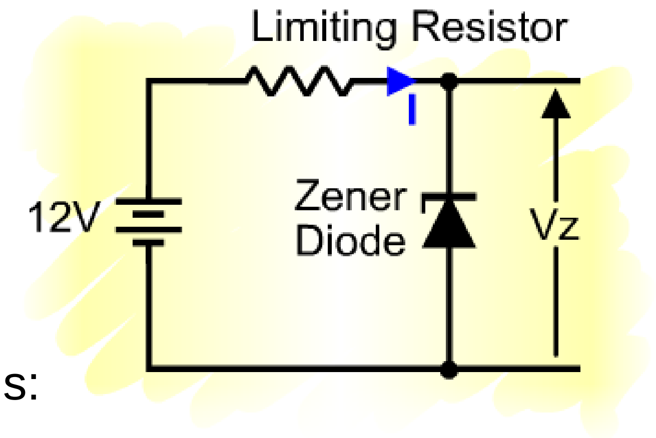
Zener Diode Datasheet

Some of the criteria, found on the product data sheet, to consider when selecting a zener diode.

- Nominal zener voltage
- Maximum zener voltage
- Minimum zener voltage
- Maximum current
- Maximum power

Zener Diode Ratings

Example
Calculate the series resistor for a 6.2V zener diode that is rated at 500mW and connected to a 12V supply.



The maximum current in the zener diode is:

$$\text{Current} = \frac{\text{Power}}{\text{Voltage}} = \frac{500\text{mW}}{6.2\text{V}} = 80.6\text{mA}$$

Voltage dropped across the series resistor is: 12 - 6.2 = 5.8V.

Therefore to limit the current to 80.6mA the minimum resistor value is:

$$R = \frac{V}{I} = \frac{5.8\text{V}}{80.6\text{mA}} = 72.0\Omega$$

From the E24 resistor range, a 75Ω resistor would keep the current to within a safe value.

Simple Power Supply with a Zener Diode

A zener diode can be used across the output of a half-wave rectifier circuit to provide a constant, steady output voltage.

A standard diode rectifies the AC input and a reservoir capacitor reduces the ripple voltage.

The zener diode is used to slice off the ripple to leave a smooth DC output voltage at the zener voltage V_Z. Note that a resistor must be used in series to prevent damage to the zener diode.