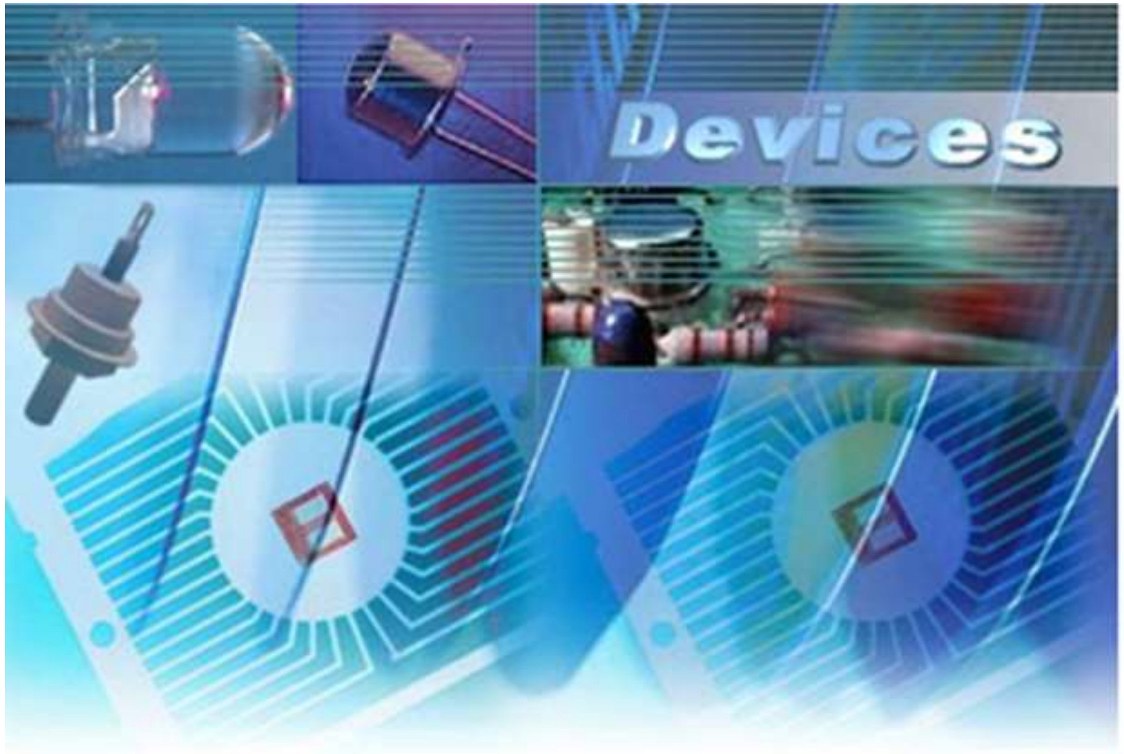
Diode Circuits

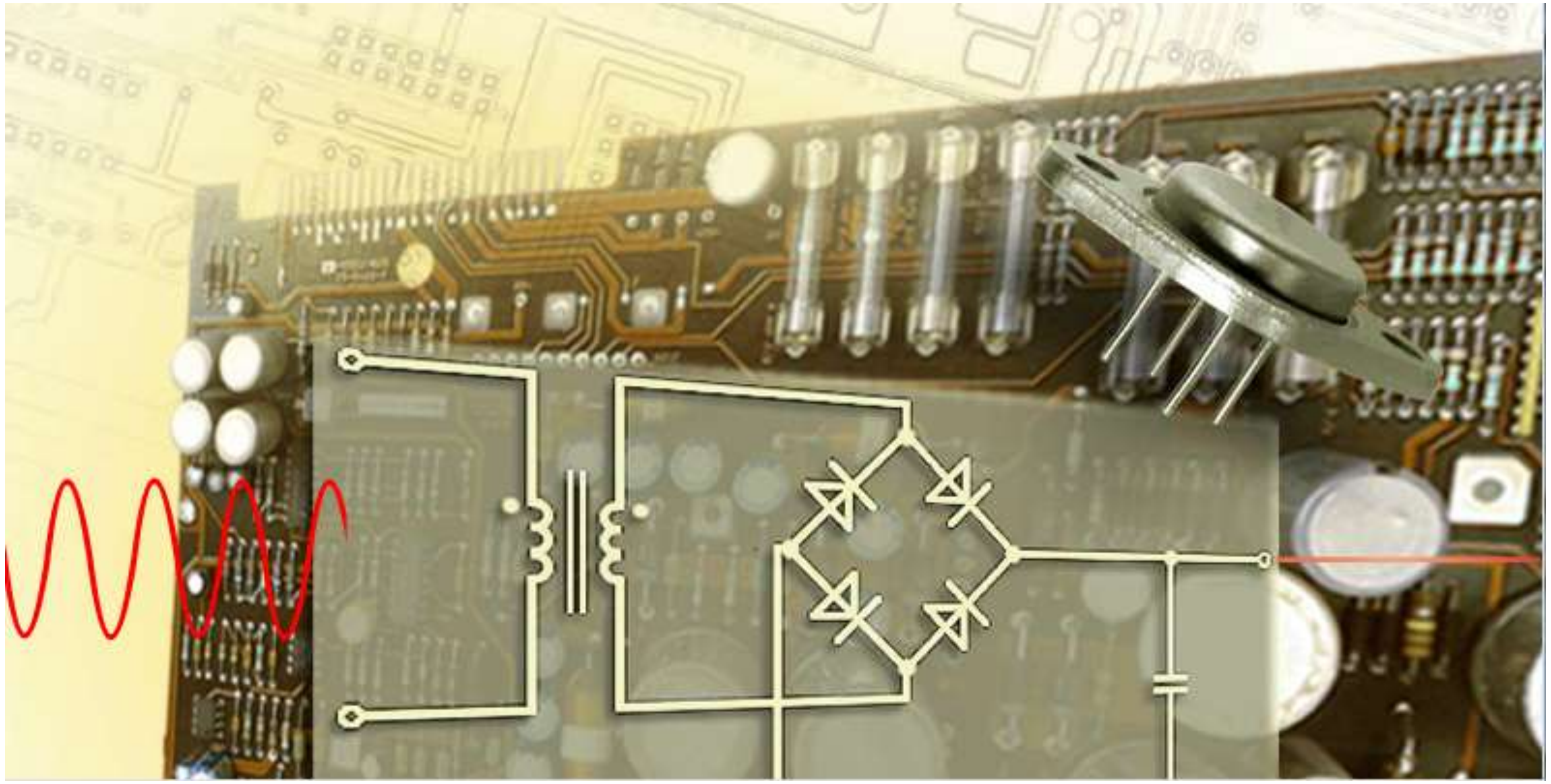


Semiconductor Elements

Last update 14.04.2020

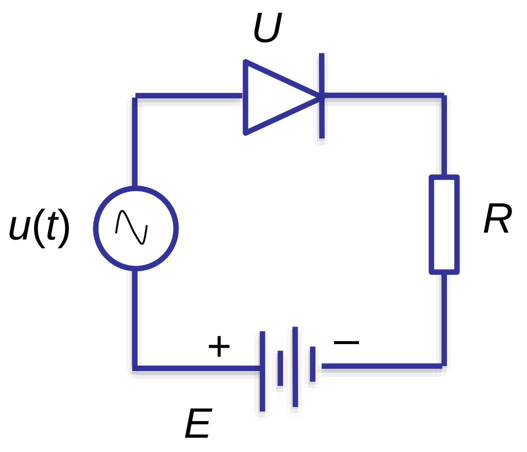
Introduction

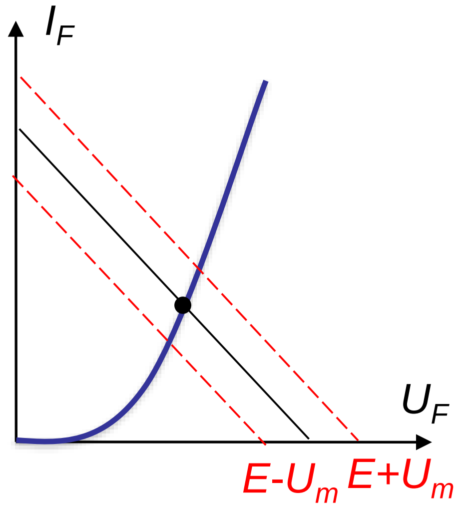
Due to their one-way conductivity, diodes are the main building blocks in rectifiers that convert the standard AC voltage (220V, 50 Hz) to DC



Work with ac signals

Most commonly, diodes are used in rectifiers and limiting circuits.

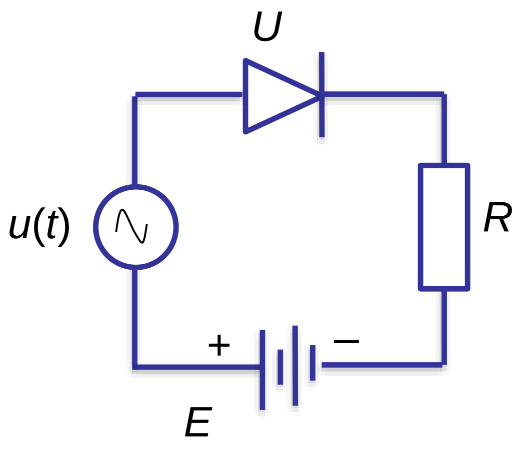


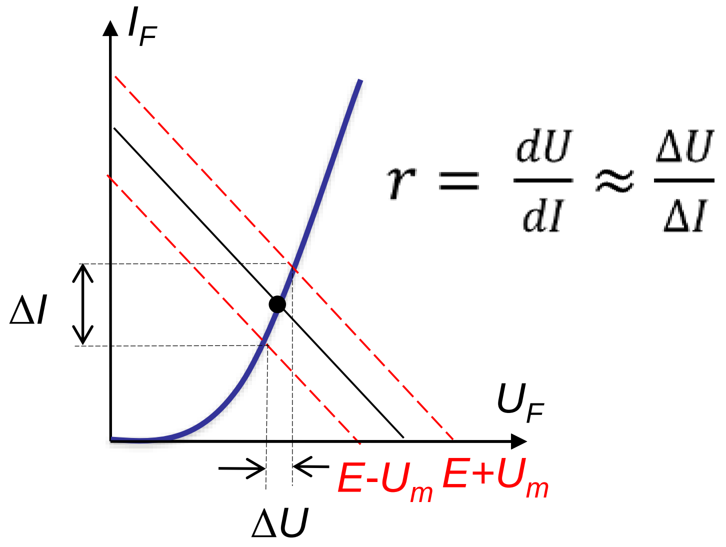


When a variable sine wave signal u (t) = $U_m$sinωt with U_m amplitude is applied to the diode in addition to the constant voltage, the maximum output voltage of the supply voltage will be $E + U_m$ and for the negative one, respectively, $E - U_m$.

Dynamic resistance

A region defined by the sinusoidal signal is formed around the operating point, in which the AC **(dynamical) resistance** of the diode is defined.



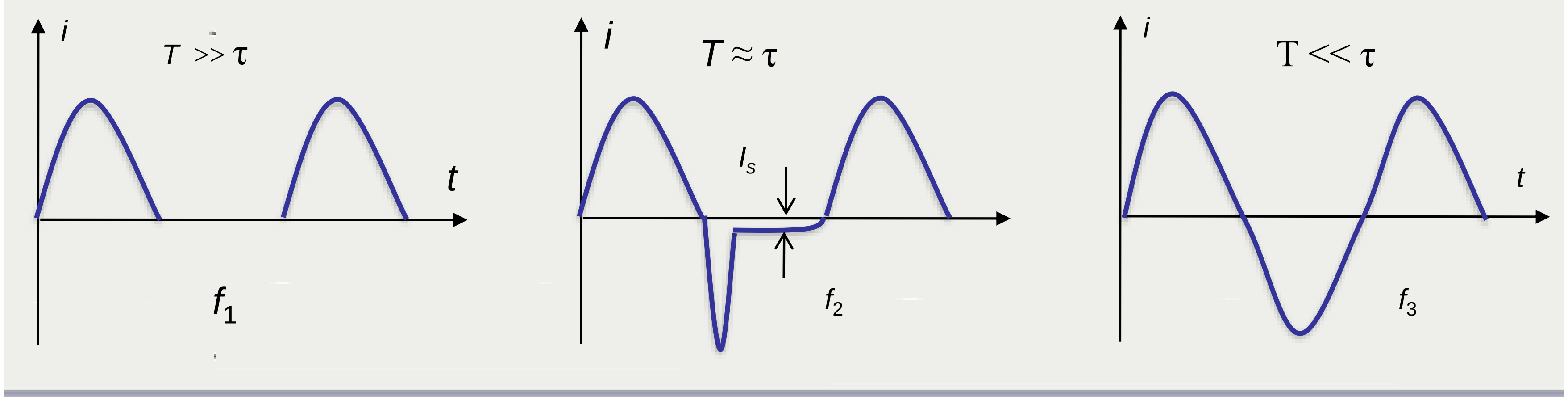


$$r = \frac{dU}{dI} = \frac{\varphi_T}{I + I_s}$$

The analytical expression for the dynamic resistance is determined by differentiating the equation of the current-voltage characteristic of the diode.

Work with high frequencies

Under sinusoidal signals of different frequency $u(t) = U_m.\sin\omega t$, where $\omega = 2\pi f$ and period $T = 1/f$, the transients processes in the diode take place over the lifetime of the minority current carriers τ.

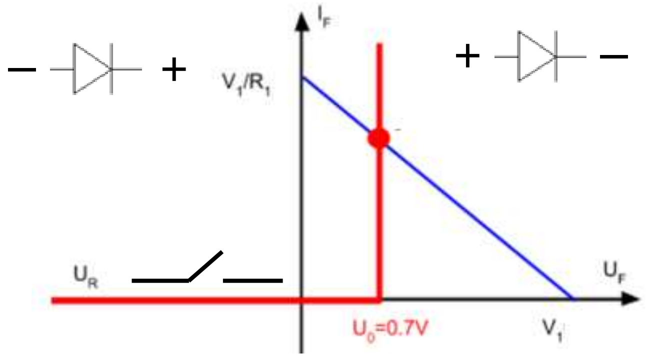


Low frequency

$f_1 << f_2 << f_3$

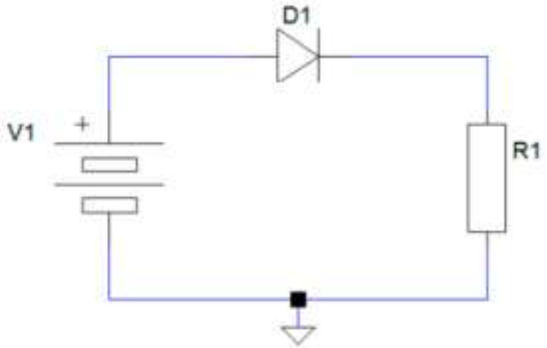
At high frequencies the diode looses one-way conductivity properties.

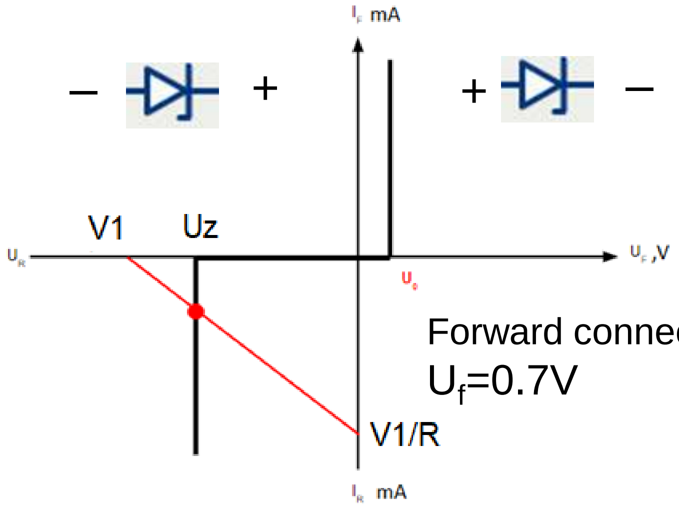
Diode and Zener Diode – review



Reverse connection
Open key I=0

Forward connection
U_f=0.7V





Forward connection
U_f=0.7V

Reverse connected Zener diode

1. Works in **breakdown** region if

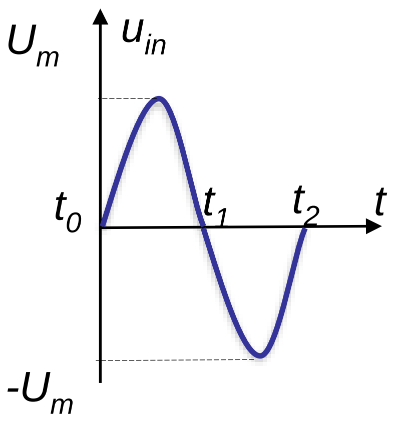
V1 ≥ Uz   U=Uz

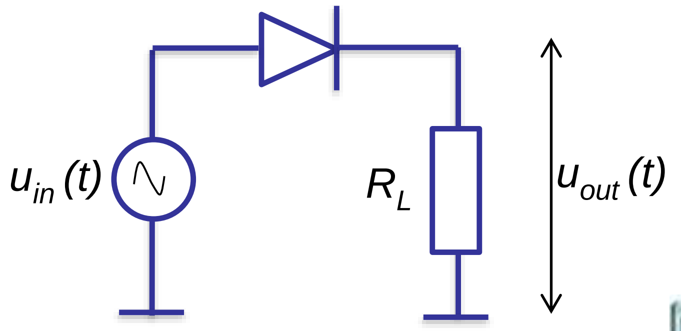
2. Act as open key if V1 < Uz   I=0

Applications – Half wave rectifier

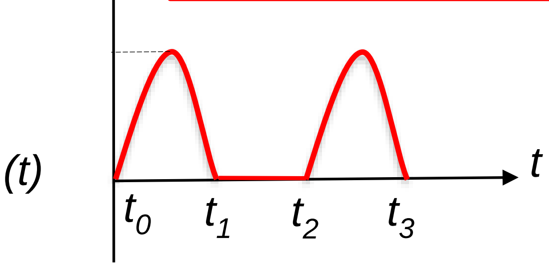
During the positive half period the diode is forward connected. The current flowing through it creates a voltage drop on the load resistance R_L. The output voltage repeats the shape of the input signal, but is less than it with forward diode voltage of 0.7V

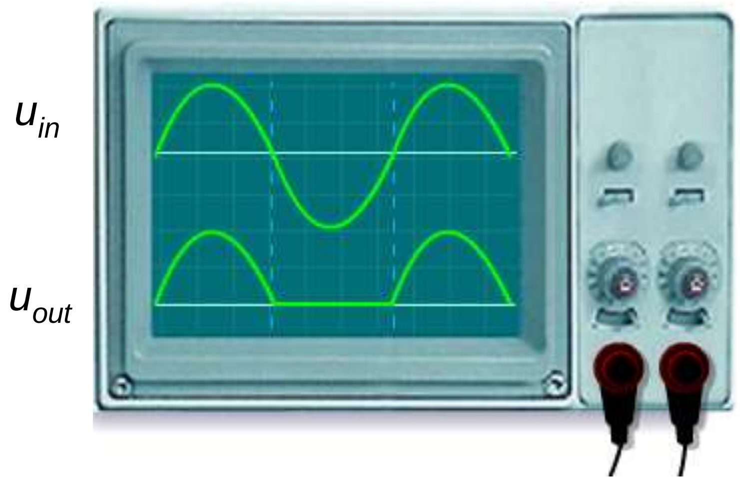
$$U_{m\,(out)} = U_{m\,(in)} - 0{,}7\ V$$





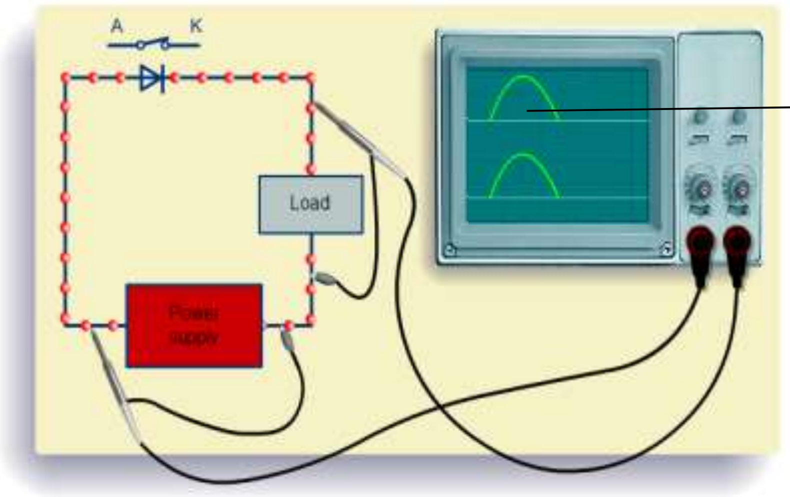
Half-way rectifier circuit





During the negative half-period, the diode is reverse connected, no current is flowing through the circuit, and the output voltage is zero.

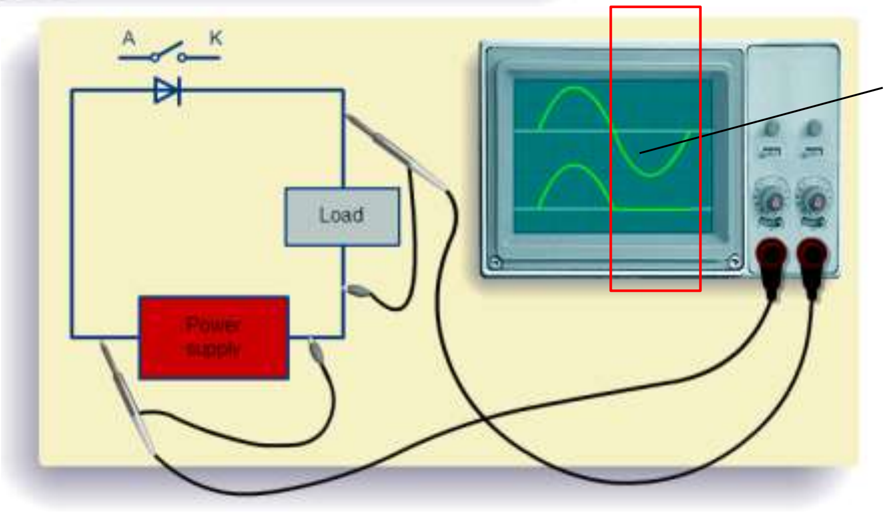
Mode of Operation



Input voltage positive half wave

Output voltage – as input voltage, but with amplitude *Um*-0.7V

Positive half wave of the input voltage

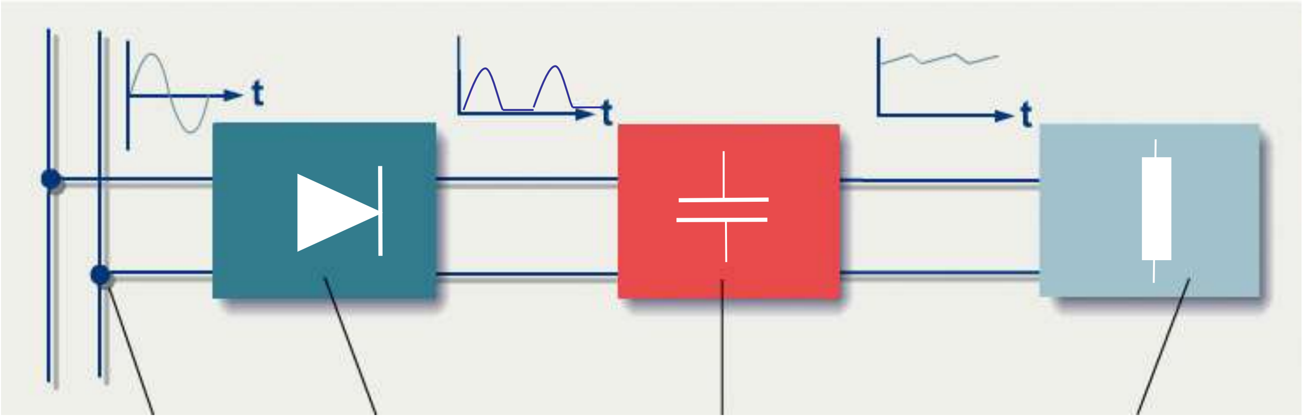


Input voltage negative half wave

Output voltage – 0V

Negative half wave of the input voltage

Smoothing Capacitor



Network Rectifier Smoothing capacitor Load

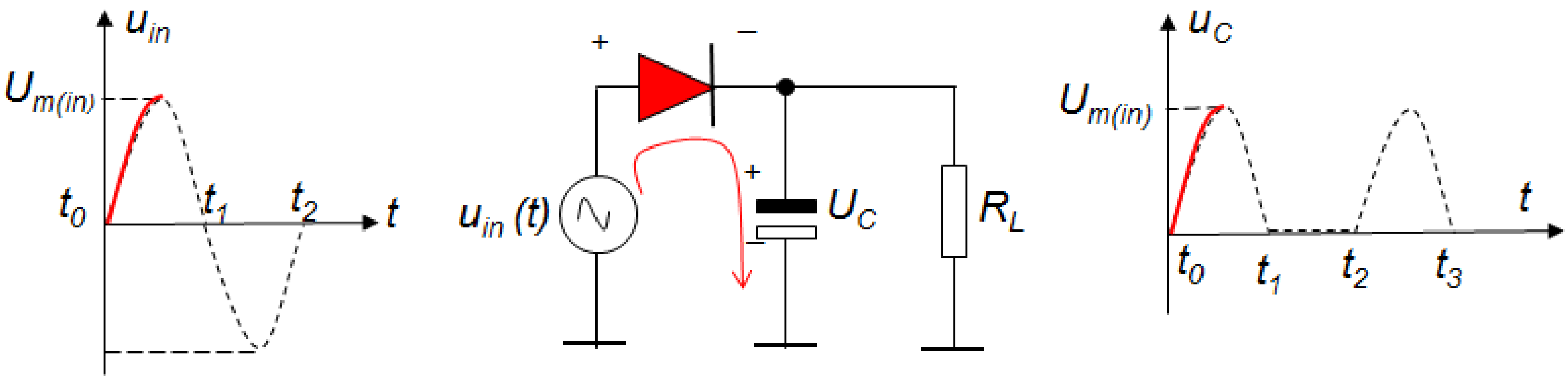
A **half wave rectifier** is defined as a type of **rectifier** that only allows one **half**-cycle of an AC voltage waveform to pass, blocking the other **half**-cycle. **Half-wave** rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct.

The proper functioning of the electronic circuits requires a DC power source. A capacitive filter is used to reduce ripples in the output voltage of the rectifier.

Mode of operation

The smoothing capacitor converts the half-wave rippled output of the rectifier into a more smooth DC output voltage.

During the positive half-period, the diode is forward connected and the current flowing through it charges the capacitor approximately to the peak value of the input voltage (if the voltage drop on the diode is neglected).



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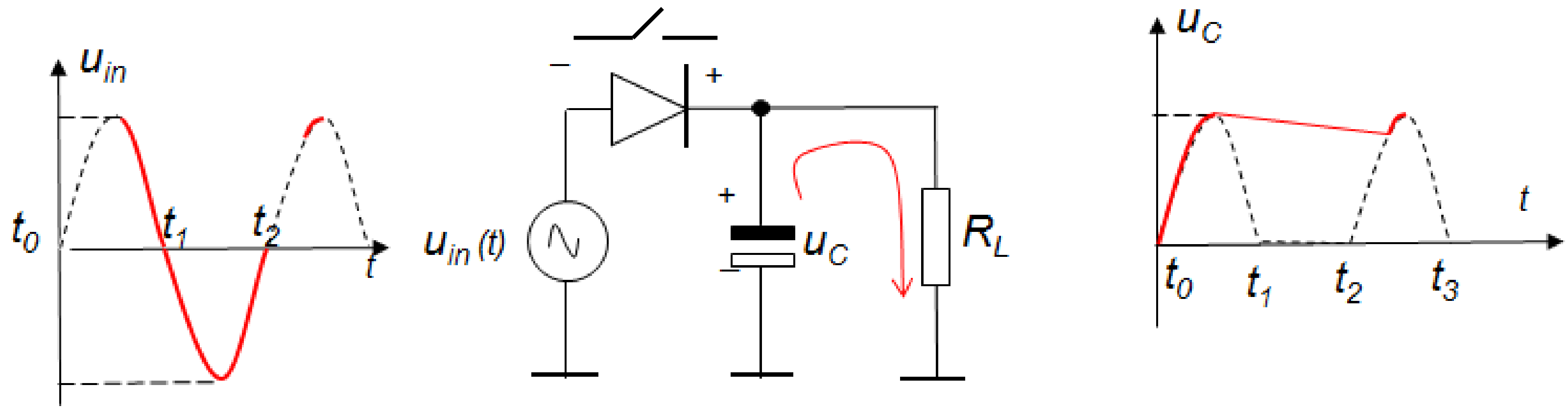
Mode of operation

When the input voltage drops below its peak value, the diode is turned off and acts as an open key. The capacitor keeps its charge and the diode switch, which is in the reverse direction, breaks the circuit to the input source.



For the rest of the cycle, the capacitor can only be discharged through the load resistance at a rate determined by the $R_L C$ time constant. The larger the time constant, the slower the capacitor will be discharged. The result is a relatively constant voltage with weak fluctuations.

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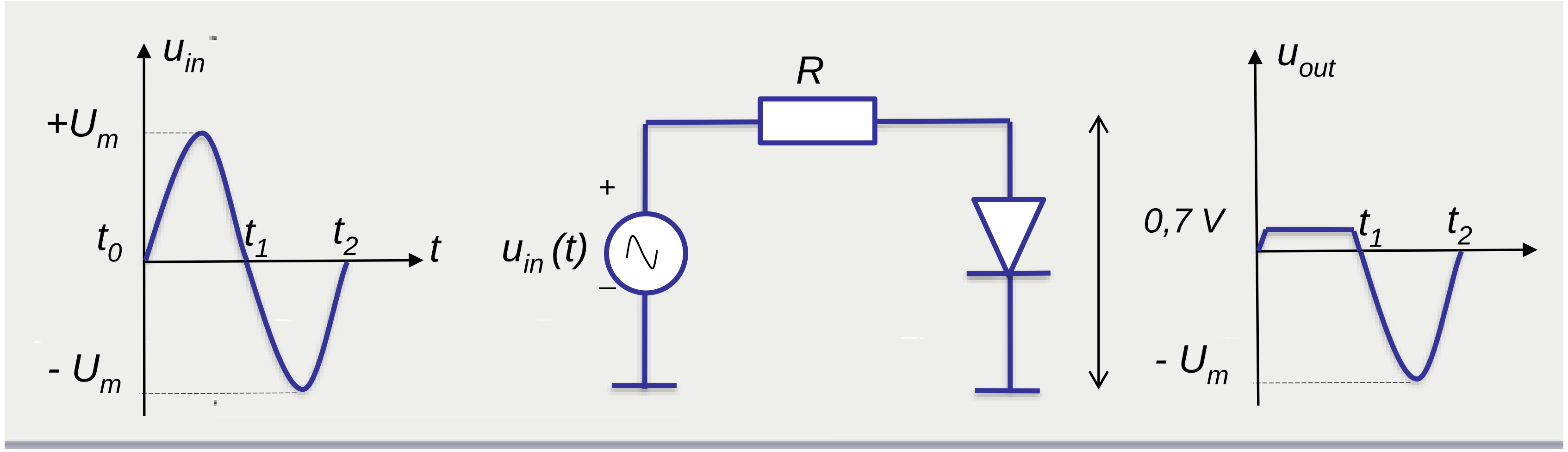
Positive Diode Clipping Circuit



Diodes are often used to cut off parts of a signal above or below a certain level. When the diode is forward connected, the voltage across it is 0.7 V. When the input voltage exceeds this value the output voltage **is limited** (clipped) to a level of 0.7V.

During the negative half-period the diode is reverse connected - it acts as an open key and the voltage at the output repeats the shape of the input voltage.

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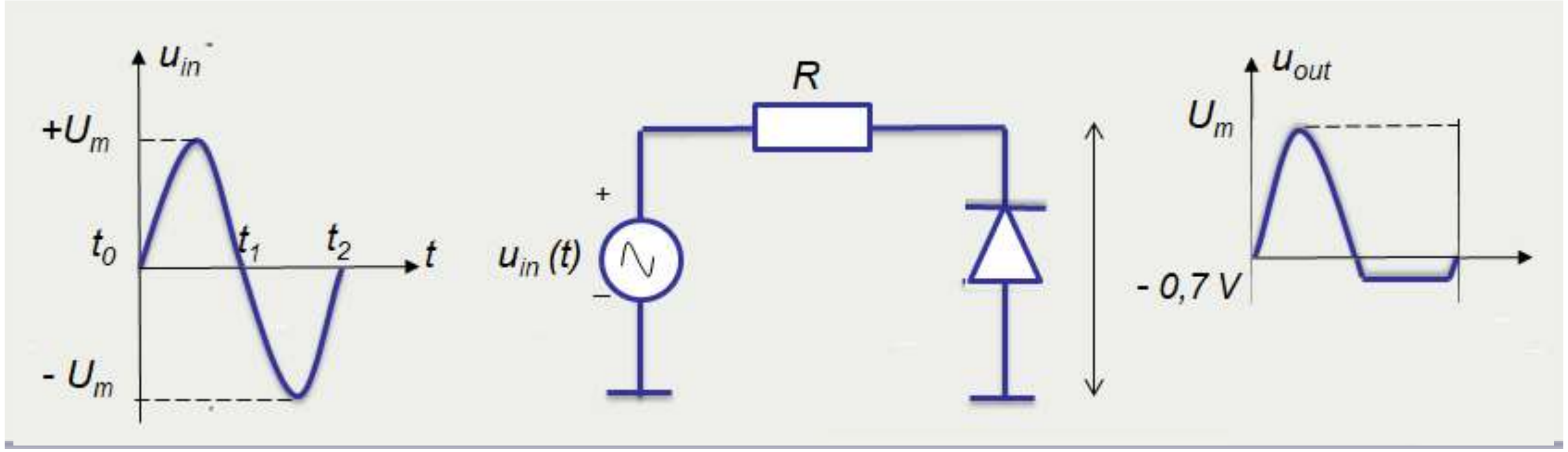
Negative Diode Clipping Circuit



The diode is forward biased during the negative half cycle of the sinusoidal waveform and limits (or clips) it to –0.7 volts.

During the positive half-period the diode is reverse connected - it acts as an open key and the voltage at the output repeats the shape of the input.

As the diode limits the negative half cycle of the input voltage it is therefore called a negative limiter (clipper) circuit.

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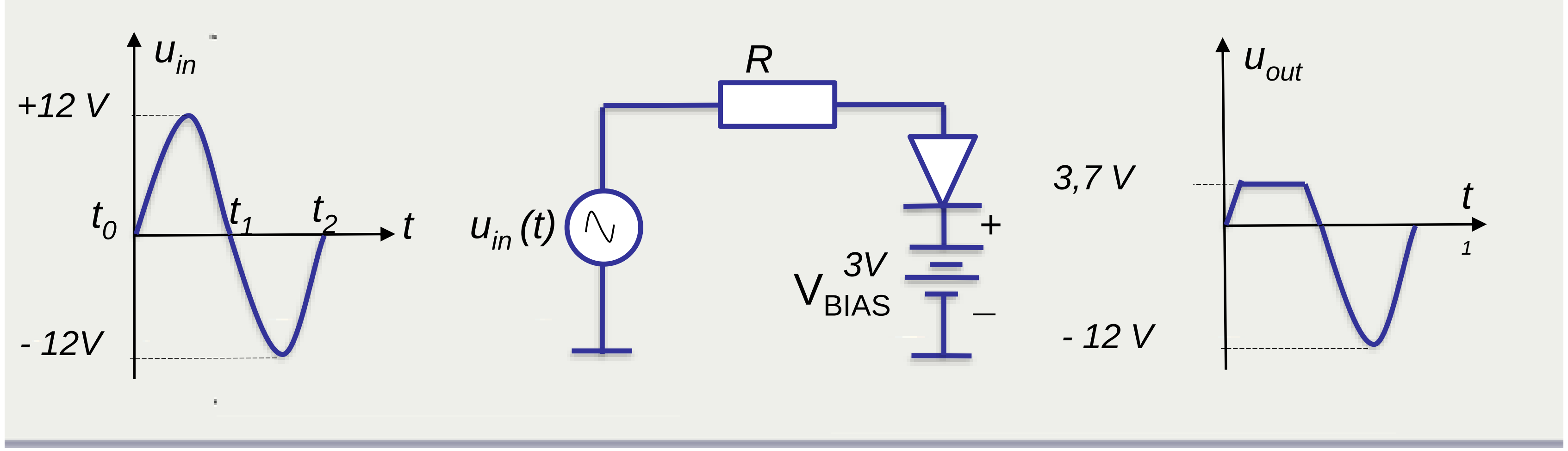
Biased Diode Clipping Circuit



To produce diode clipping circuits for voltage waveforms at different levels, a bias voltage, V_{BIAS} is added in series with the diode to produce a combination clipper as shown.

The diode will be forward connected when the voltage at its anode exceeds the sum of the battery voltage value and voltage 0.7V on the diode. Then the output voltage is limited to this value (3.7V in this case) and all higher input voltages are cut off.

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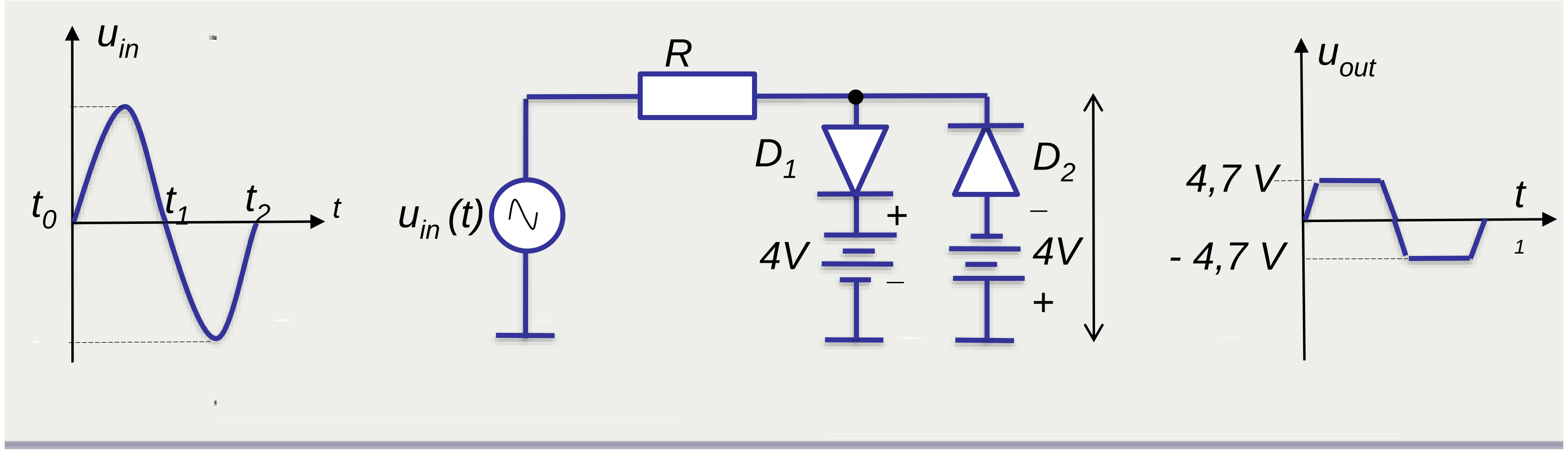
Full-wave Biased Diode Clipping



When the input voltage exceeds + 4.7 V, diode D1 is forward connected and limits the input voltage to + 4.7 V.

The diode D2 is in forward connection when the voltage reaches - 4.7 V. Therefore, positive voltages above 4.7 V and negative below - 4.7 V are cut off.

For voltages below +4.7V and -4.7V the respective diodes are in reverse direction, act as open keys and output voltage repeats the input one.

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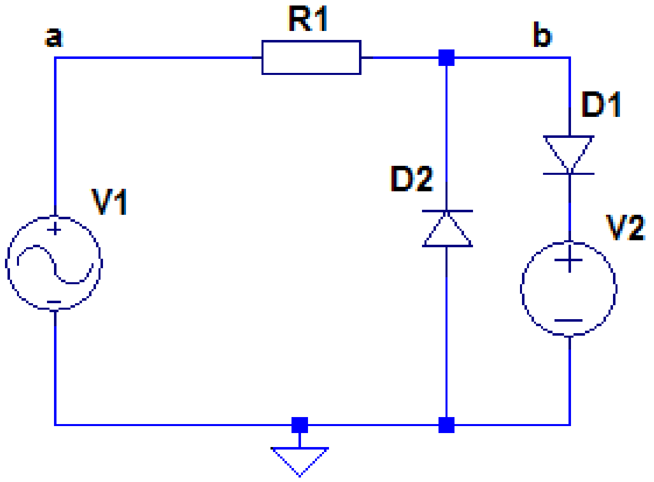
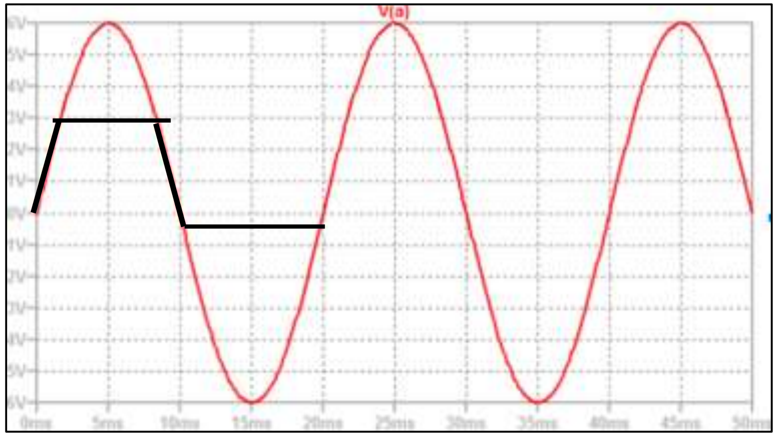
Example





Input signal

D1 has Uo=0.6 V. V2 is the battery with voltage 2.4 V. Input waveform is sine wave with amplitude 6V. What will be the voltage limit for both half waves?

In positive half wave D1 is in forward connection and the voltage is clipped at 2.4+0.6 = 3V. In negative half wave D2 is forward connected and the output voltage is limited to -0.6 V.

For voltages less than 3V the diode D1 is reverse biased, act as open key and the output voltage follows the input one.

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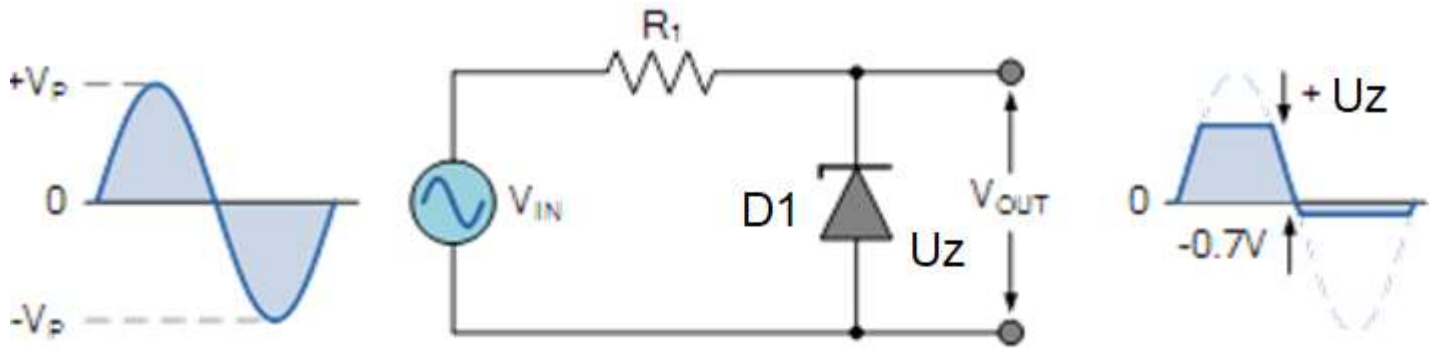
Zener Diode Clipping Circuits



One easy way of creating biased diode clipping circuits without the need for an additional voltage supply is to use Zener Diode. The zener diode is acting like a biased diode clipping circuit with the bias voltage being equal to the zener breakdown voltage.

During the positive half wave, when the input voltage increase over the Zener breakdown voltage Uz, the diode D1 works in breakdown region, so limiting the output waveform at the level of zener voltage Uz. During the negative half cycle the zener acts like a normal forward connected diode with its usual 0.7V value.

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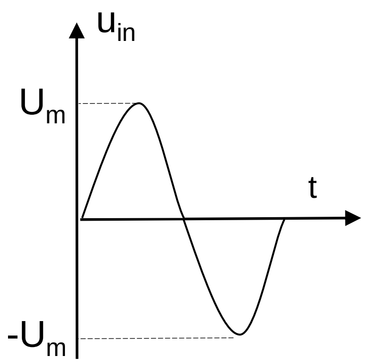
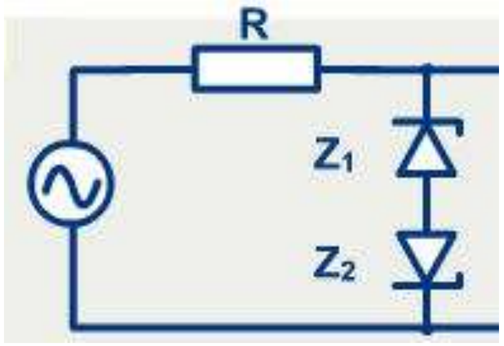
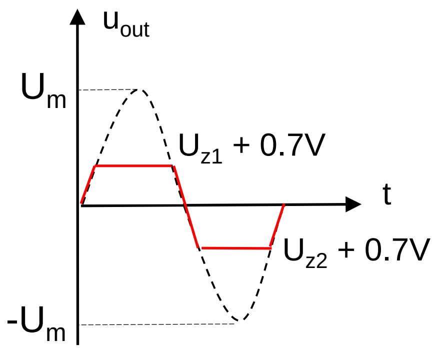
Full-wave Zener Diode Clipping







The output waveform will be clipped at the zener voltage plus the 0.7V forward volt drop of the other diode.

On the positive half cycle, the diode Z_1 breaks down and the diode Z_2 is forward biased. The output is then clipped at the clipping level equals the breakdown voltage U_{Z1} of the Z_1 plus 0.7V of forward-biased diode Z_2.(U_{Z1} + 0.7V)

On the negative half cycle, the diode Z_2 breaks down and the diode Z_1 is forward biased. The output is then limited at the clipping level equals U_{Z2} of the Z_2 plus 0.7V of forward-biased diode Z_1 (U_{Z2} + 0.7V)

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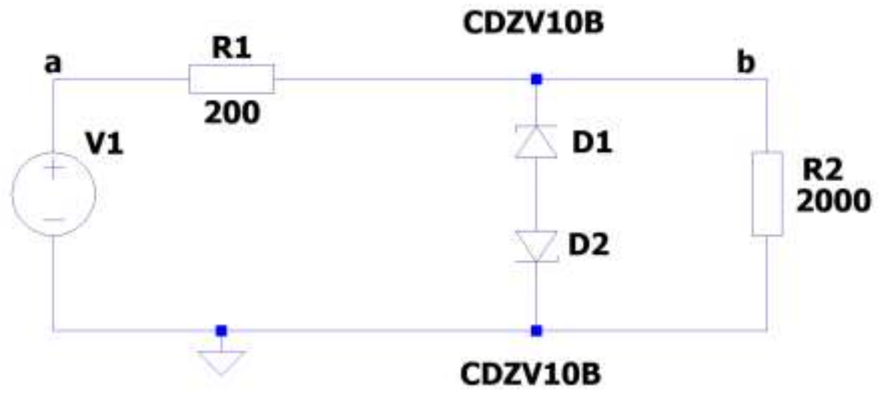
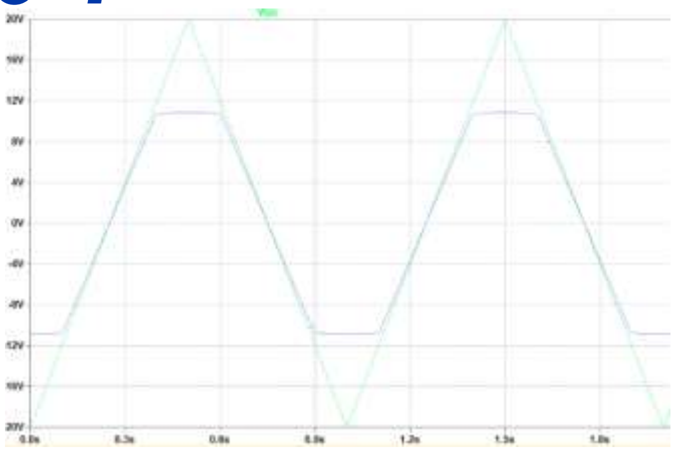
Example 1





Both diodes have breakdown voltages Uz=10V. The input waveform is triangular signal with voltages changed between -20V and + 20 V.

During the positive half period the diode D1 is in the breakdown and diode D2 is in the forward connection. The output voltage is limited to Uz + Uo = 10+0.7=+10.7 V. During the negative half period D2 is in breakdown, D1 is forward connected and the voltage is limited to -10.7V

When the input voltage is less than the Zener breakdown voltage, the respective zener diode is in reverse connection and the output voltage follows the input one

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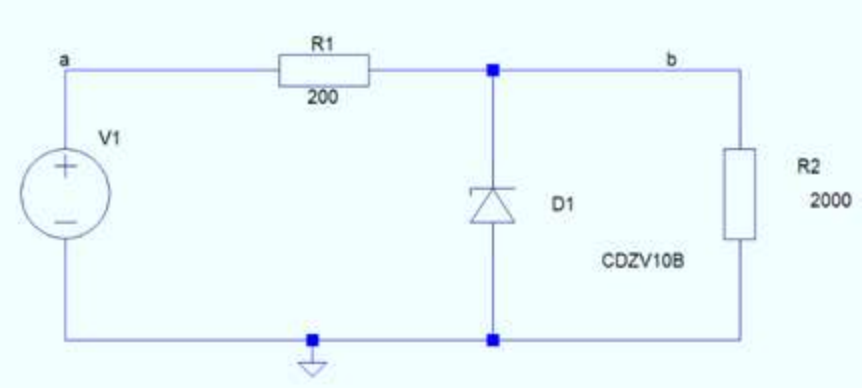
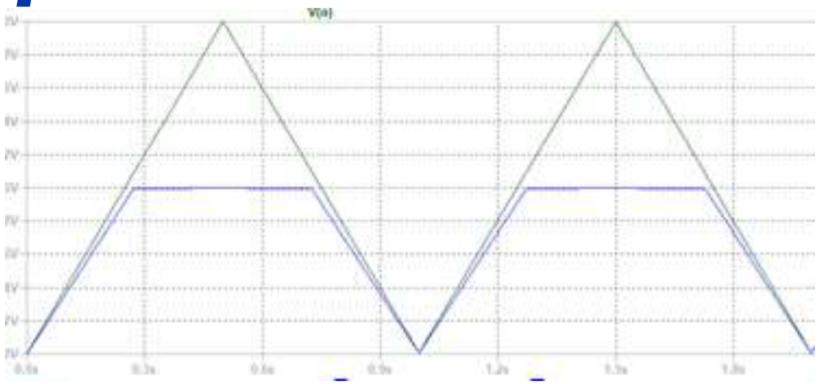
Example 2





The diodes has a breakdown voltage Uz=10V. The input waveform is triangular signal with voltages changed between 0V and + 20 V.

With positive input signal (from 0V to 10V), which is less the breakdown voltage, the Zener diode is in reverse connection, acts as open key and the output voltage follows the input voltage.

When the voltage reaches zener breakdown voltage Uz and is higher than 10V the zener diode works in breakdown mode. The output voltage is limited to Uz=10V. When the input voltage falls less than Uz , the output voltage again follows the input.

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