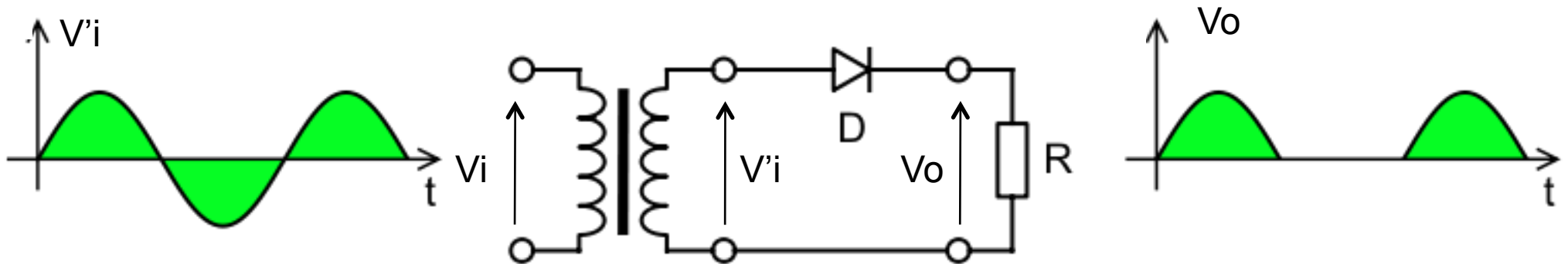


# Rectifiers

The simplest version of rectifier circuits is [the half wave rectifier](#)

The circuit is made by a single diode (the transformer is used both to decouple the load from the mains and to change the value of output voltage with respect to the input one).

Either the positive or negative half of the AC wave is passed, while the other half is blocked. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer.



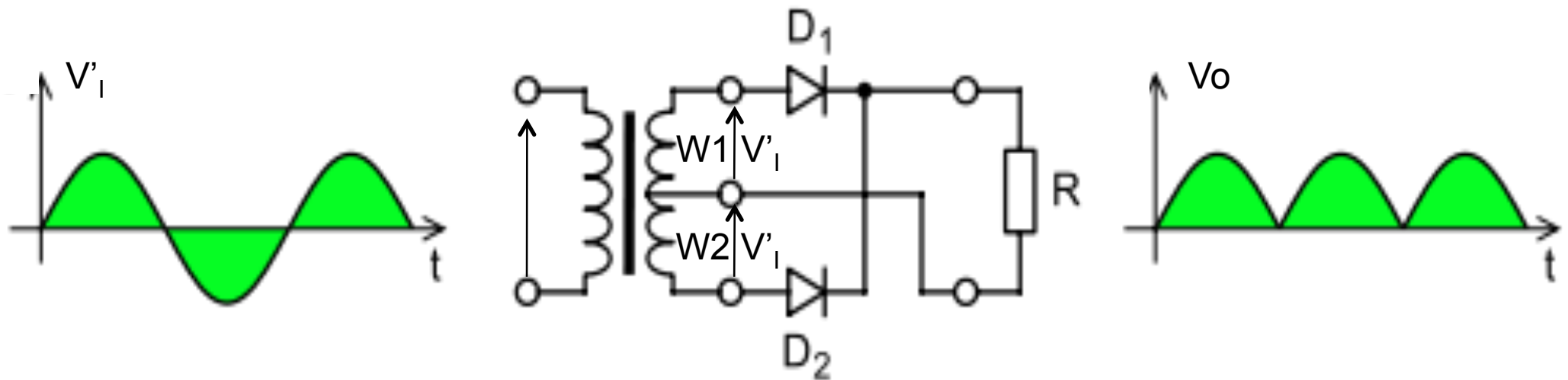
The output DC voltage of a half wave rectifier can be calculated with the following relation:

$$V_{OAV} \equiv V_{ODC} = \frac{1}{T} \int_0^{T/2} V'_{IMAX} \sin \omega t dt = \frac{V'_{IMAX}}{\pi}$$

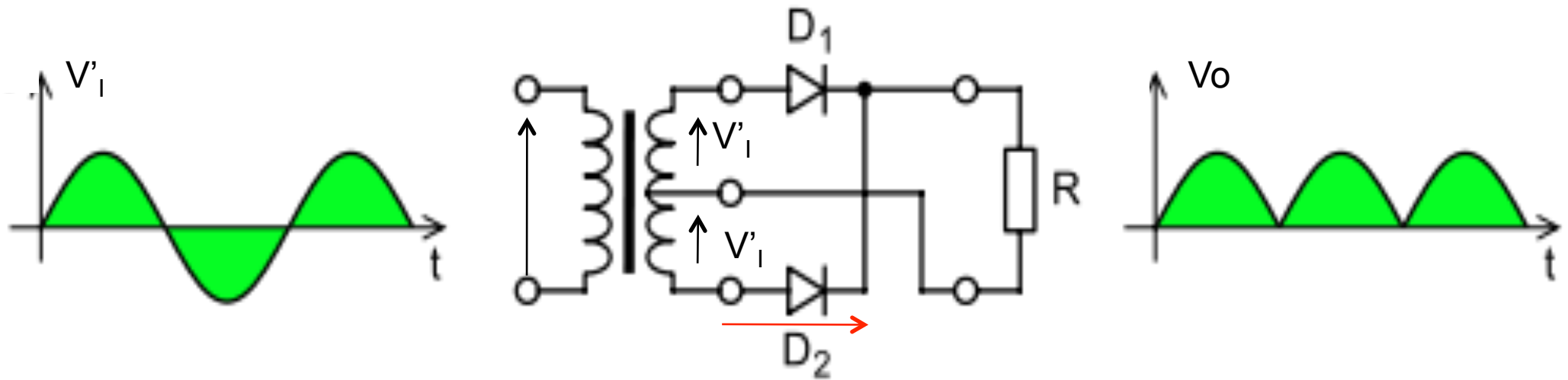
The max reverse voltage that be sustained by the diode is:  $V_{RMAX} = V'_{IMAX}$

## The Full-Wave Rectifier

A better solution is the **full-wave rectifier**. The circuit requires two diodes arranged so that load current flows in the same direction during each half cycle of the ac supply. A schematic of a simple full-wave rectifier is shown in figure



In that circuit a transformer is needed that has a center-tapped, high-voltage secondary winding divided into two equal parts ( $W1$  and  $W2$ ).  $W1$  provides the source voltage  $V_1$  for  $D1$ , and  $W2$  provides the source voltage (negative)  $V_1$  for  $D2$ . The connections to the diodes are arranged so that the diodes conduct on alternate half cycles, causing current to flow through the load resistor in the direction shown by the arrow both in the positive and negative half cycle of the a.c. input.

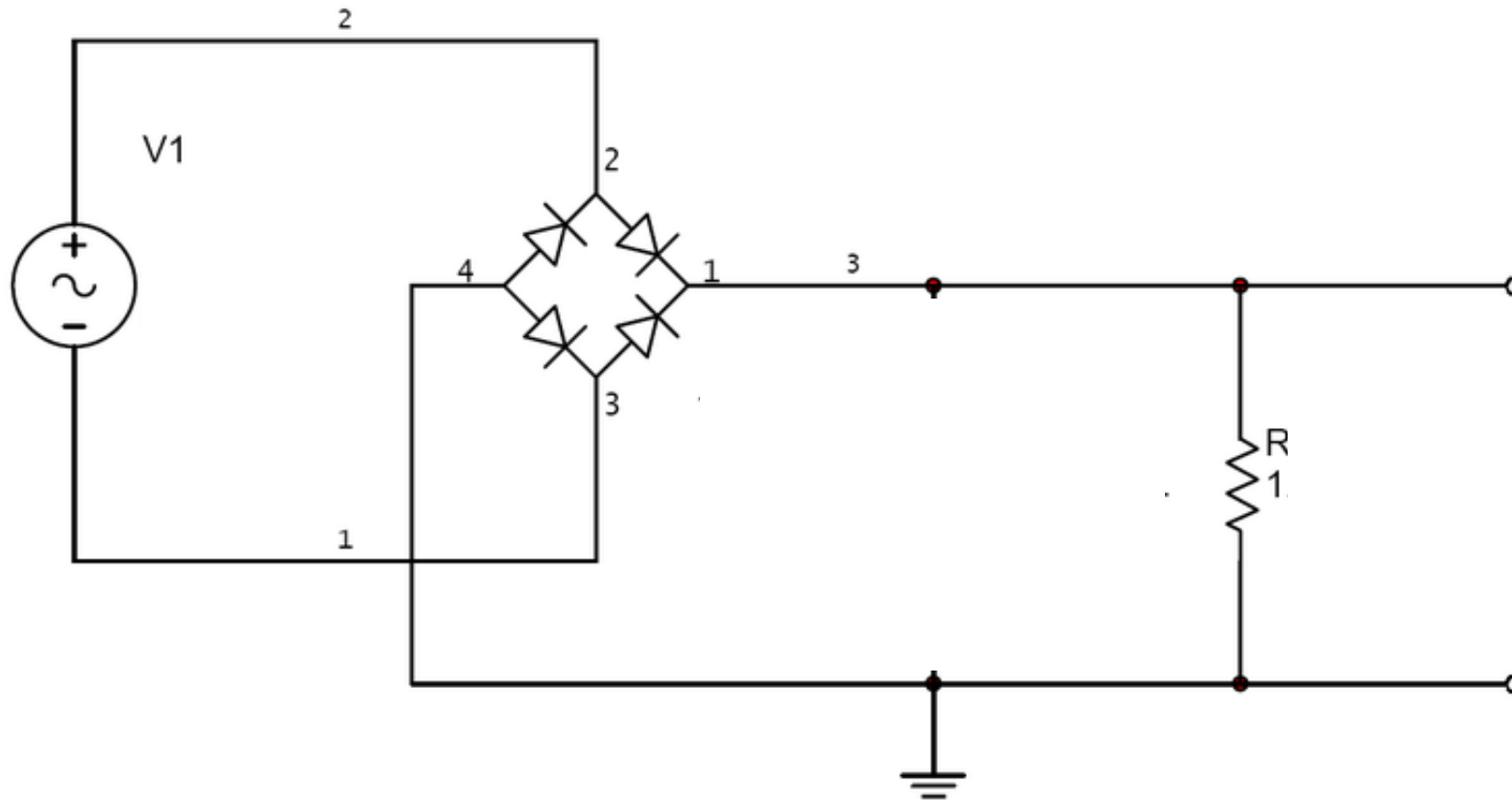


The output DC voltage of a half wave rectifier can be calculated with the relation:

$$V_{OAV} \equiv V_{ODC} = \frac{2}{T} \int_0^{T/2} V'_{IMAX} \sin \omega t dt = \frac{2V'_{IMAX}}{\pi}$$

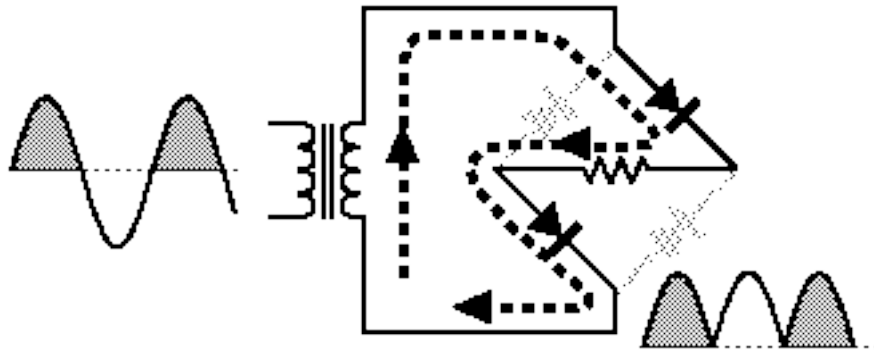
The max reverse voltage that be sustained by each diode is:  $V_{RMAX} = 2 V'_{IMAX} = 2V_{OMAX}$  because when one diode is reverse biased, the other is forward biased, so the entire voltage  $2V'_1$  at the secondary winding of the trasformer is applied to the reverse biased one, that is 2 times the max voltage  $V_{OMAX}$  at the output.

A different solution for the full wave rectifier is given by that circuit that is named **Bridge rectifier**

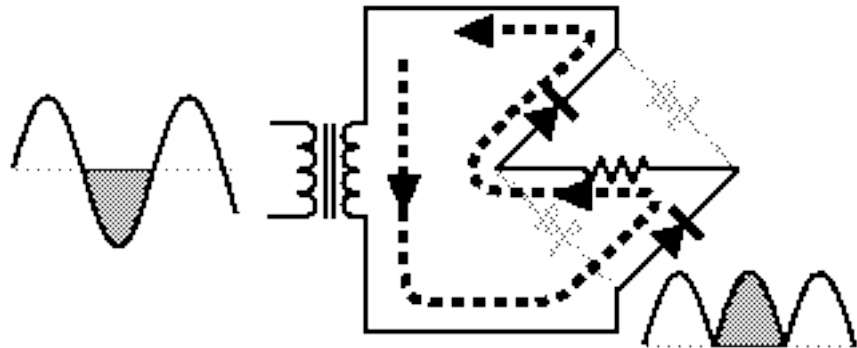


In the above circuit, there is not need of a center tap transformer (the transformer can be used to decouple the output ground from the input one, or to change the value of output voltage with respect to the input one).

One can easily understand the principle of operation with reference to the following schematics:



a) During the positive half period of the input voltage , assuming the same polarity at the transformer secondary, the current flow is the one indicated by the arrow, and two diodes (in series) are conducting, while the other two are reverse biased



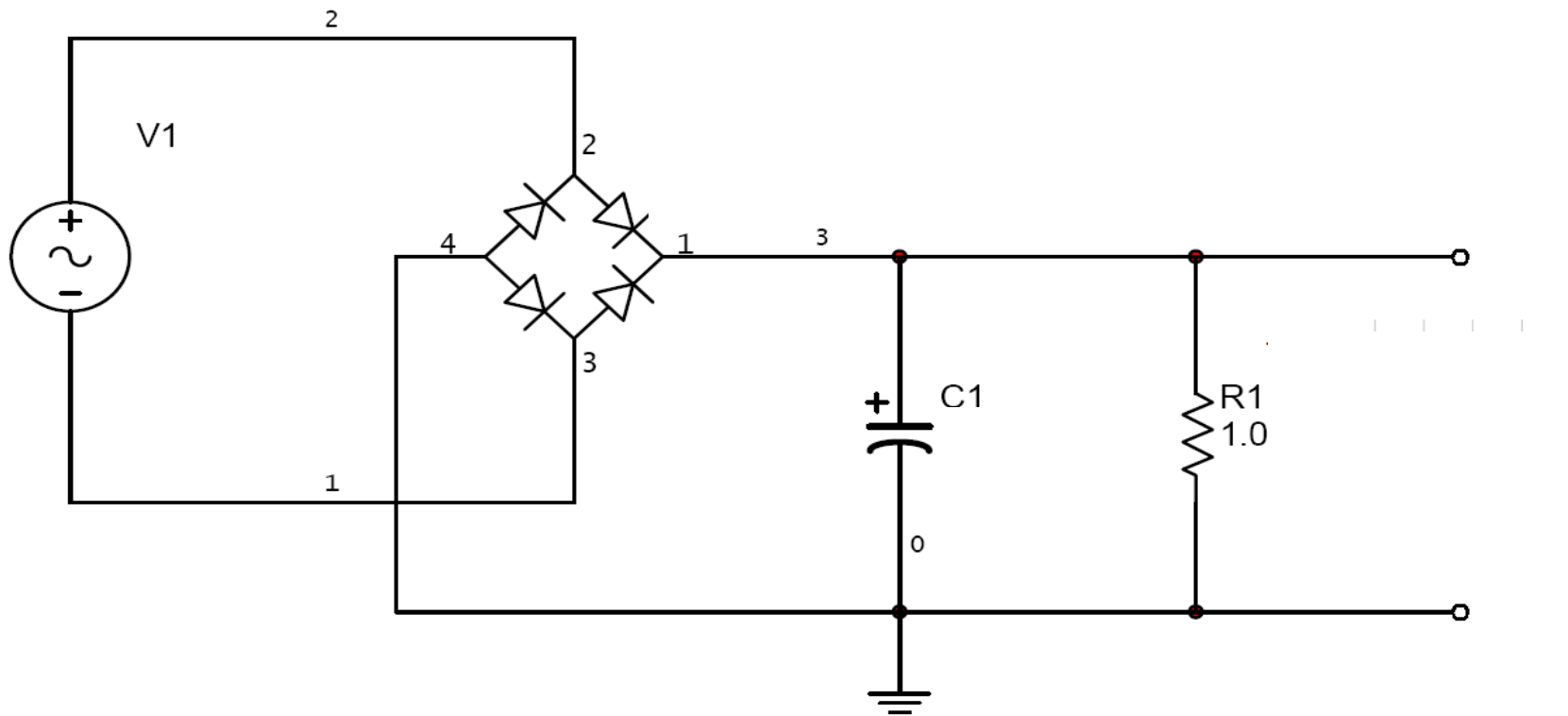
b) During the negative half period of the input voltage the current, indicated by the arrow, will flow in the same direction into the load, with the other two diodes (in series) conducting, and the other two reverse biased

The max reverse voltage that be sustained by each diode is now:  $V_{RMAX} = V'_{IMAX} = V_{OMAX}$  because both the reverse biased diodes are in parallel with the output; so the max reverse voltage is  $V'_I$  or the max voltage  $V_{OMAX}$  at the output.

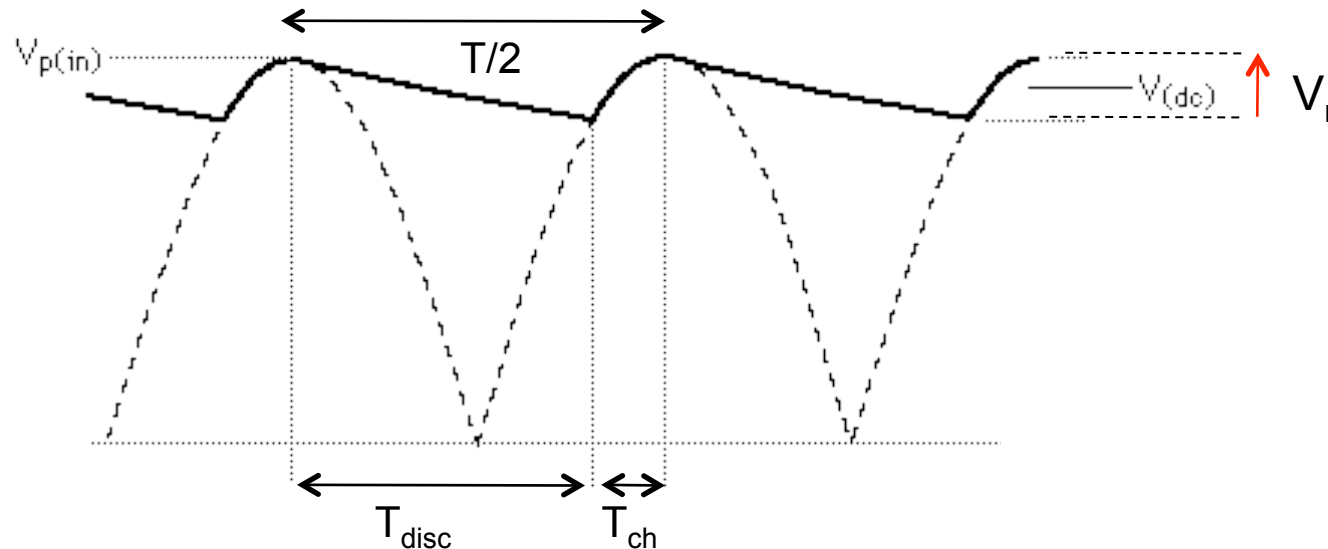
## Rectifiers with RC filter

In all rectifier circuits, the output voltage varies from  $V_{OMAX}$  to zero during each cycle: this is not acceptable for most loads (and for all electronic circuits assumed as load).

We need to filter the high harmonics of the output and leave mainly the d.c. component. The above can be done by using an RC filter, done by adding a capacitance between the bridge and the load, as indicated in the schematic below, referred, for the sake of simplicity, to the version without transformer..



The capacitance will charge to  $V_{O\text{MAX}}$  (and also  $V_{IP\text{peak}}$ ) during the increase of voltage and then it will discharge slowly during the decrease of the input voltage, provided the the time constant of the RC filter is larger than the half the period of the input voltage (as indicated in the following plot for the steady state)



the ripple factor is defined as  $V_r/V_{O\text{MAX}}$

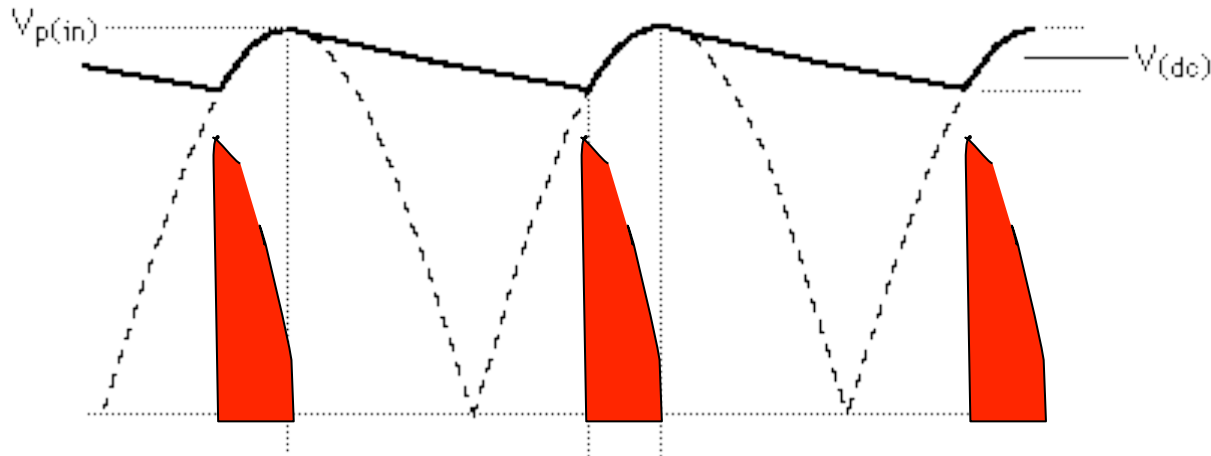
Compute the ripple factor: during the discharge, the voltage  $V_C$  across the capacitance is:

$$V_C = V_{IP} \exp\left(-\frac{t}{RC}\right) \quad \text{If the time constant } RC \text{ is much larger than } T/2, \quad T_{DISC} \cong T/2 \quad \text{and:}$$

$$V_{O\text{min}} \cong V_{IP} \left(1 - \frac{T/2}{RC}\right) \quad \text{Then:} \quad V_r = V_{IP} \frac{T}{2RC}$$

Then the ripple factor is inversely dependent on the time constant  $RC$  and can be reduced by choosing  $RC$  very large

However, the increase of the time constant  $RC$  of the filter, will lead to a very large current flowing for the time  $T_{CH}$  into the conducting diodes, as indicate in the sketch below:



In red the current plot into the conducting diodes

The area (in red) of the current waveform into the conducting diodes is the total charge  $Q_C$  charging the capacitance, and it should be equal to the charge absorbed by the load, that is approximately: 
$$Q_L \equiv \frac{V_{DC}}{R} \left( \frac{T}{2} - T_{CH} \right)$$

For high  $RC$  values, the time  $T_{CH}$  will decrease and then the current peak into the diodes can be unacceptably larger, leading to a large voltage drop across the diodes and to a decrease of the power efficiency of the circuit. Usually a time constant  $RC = 50T$  is chosen to reduce the ripple factor to a  $1/100$  of the d.c. value.

A better solution is to use a  $LC$  filter that will reduce the peak current into the diodes, while reducing the output ripple.