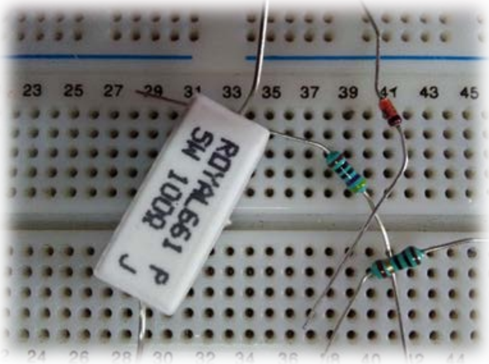
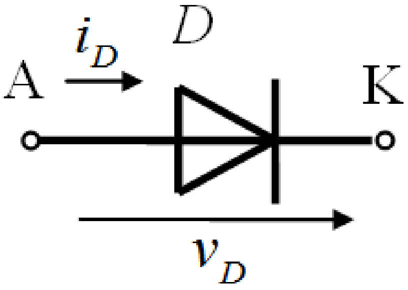
ELECTRONIC DEVICES

Assist. prof. Laura-Nicoleta IVANCIU, Ph.D.

C3 – DR switching circuits



Previously on ED (C2):



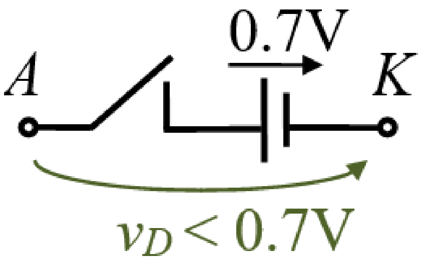
Exponential model

$$i_D \cong I_S e^{\frac{v_D}{nV_T}}$$

Constant voltage drop model

$v_D < 0.7$ V

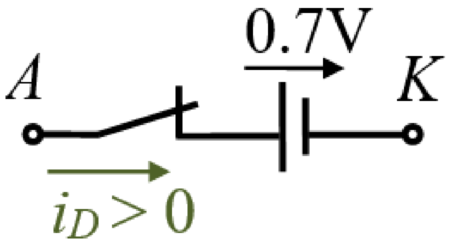
D – **(off)**



$$\begin{cases} v_D < 0.7\text{ V} \\ i_D = 0 \end{cases}$$

$v_D > 0.7$ V

D – **(on)**

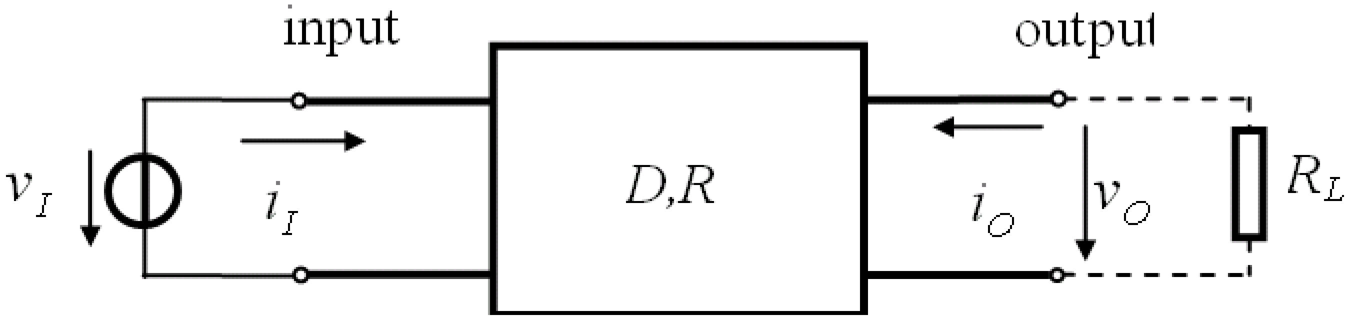


$$\begin{cases} v_D = 0.7\text{ V} \\ i_D > 0 \end{cases}$$

Contents

- Two-port DR networks. DR switching circuits.
- Voltage transfer characteristic (VTC)
- Two-port DR networks analysis
- Applications of two-port DR networks
  - Half-wave rectifier
  - Pulses selector
  - Voltage limiter
  - Maximum multi-port networks
  - Minimum multi-port networks

Two-port DR networks. DR switching circuits.



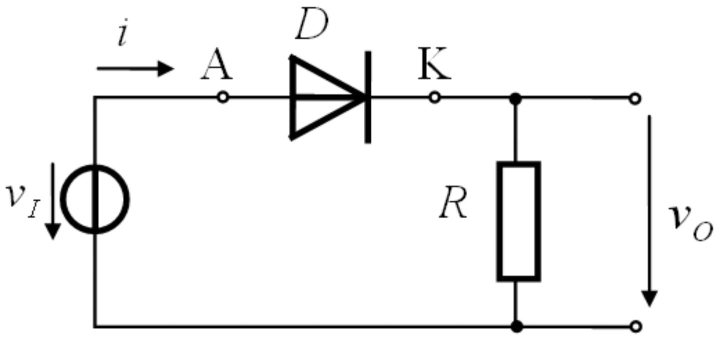
Two-port network = circuit w/ two ports – input, output

Two-port DR network = DR circuit w/ two ports – input, output

Switching two-port DR network = DR circuit w/ two ports, D – (on), (off)

The analysis of switching two-port DR networks works with the constant voltage drop model of the diode.

Voltage transfer characteristic



Voltage transfer characteristic (VTC)

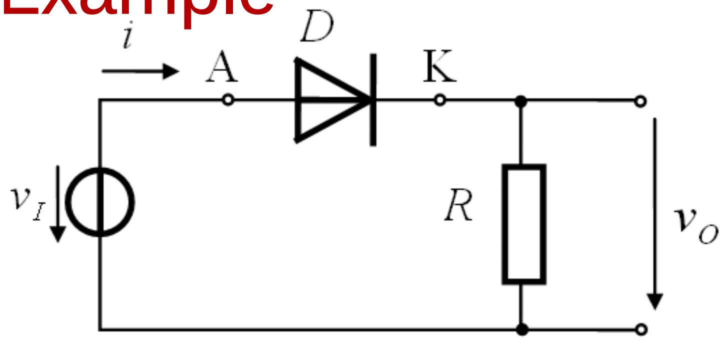
graphical illustration of $v_O(v_I)$

Steps for deducing the VTC:

- Take into account all possible situations that result from the combination of diode states (*on, off*)
- For each situation,
  - draw the equivalent circuit
  - find v_O
  - determine the range of v_I
- Plot the VTC.

Two-port DR networks analysis

Example



Deduce and plot VTC v_O (v_I)

Step 1. Write down KVL and Ohm's law for the circuit (circuit's equations)

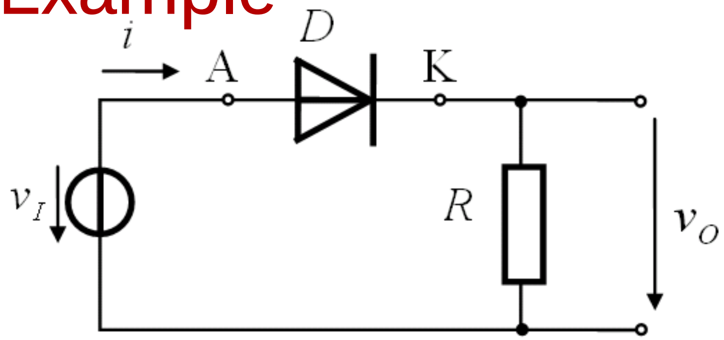
Step 2. Draw the equivalent circuits for D-(on) and D-(off)

Step 3. Find v_O and the range for v_I by replacing the diode's equations in the circuit's equations.

Step 4. Write down the complete expression of VTC v_O (v_I) and plot it, for D-(on) and D-(off).

Two-port DR networks analysis

Example



Deduce and plot VTC v_O (v_I)

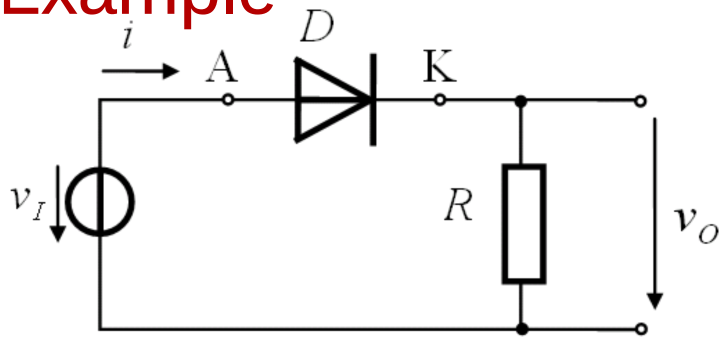
Step 1. Write down KVL and Ohm's law for the circuit (circuit's equations)

$$\boxed{\begin{array}{l} -v_I + v_D + v_O = 0 \\ v_O = i_D R \end{array}}$$

! Always valid, regardless of the state of the diode!

Two-port DR networks analysis

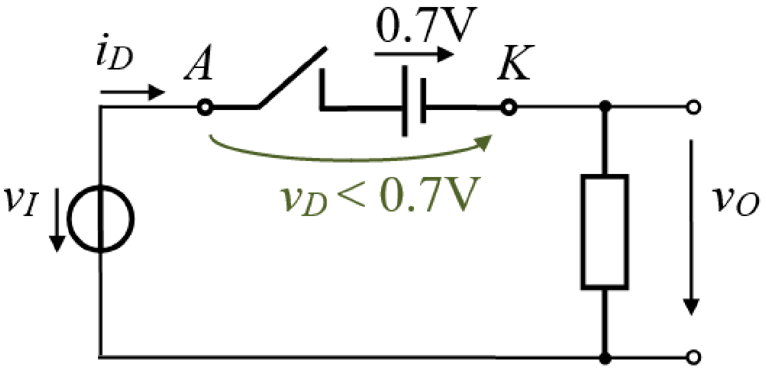
Example



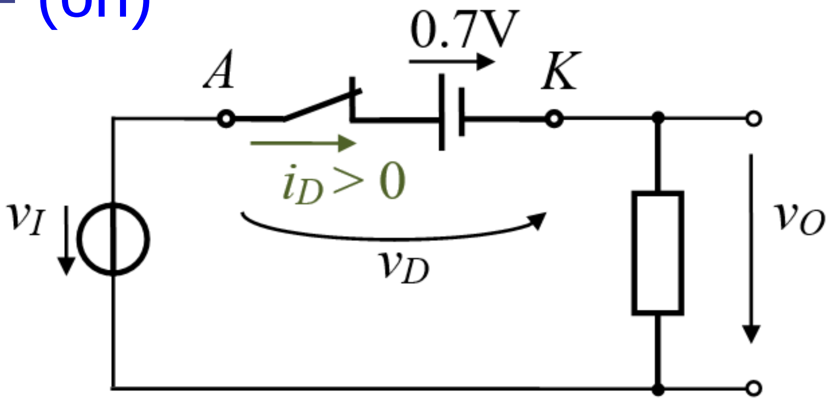
Deduce and plot VTC v_O (v_I)

Step 2. Draw the equivalent circuits for D-(on) and D-(off)

D – (off)

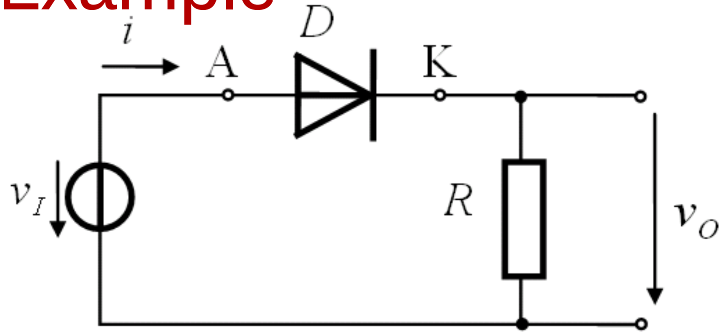


D – (on)



Two-port DR networks analysis

Example

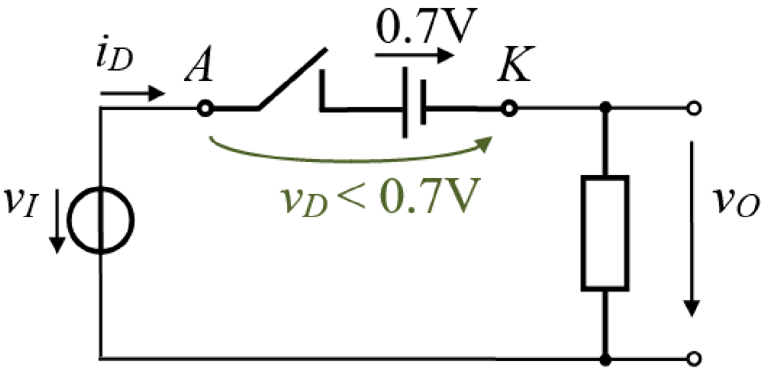


Deduce and plot VTC v_O (v_I)

Step 3. Find v_O and the range for v_I by replacing the diode’s equations in the circuit’s equations.

$$\boxed{\begin{aligned} -v_I + v_D + v_O &= 0 \\ v_O &= i_D R \end{aligned}}$$

D – (off) $\begin{cases} v_D < 0.7\text{V} \\ i_D = 0\text{A} \end{cases}$

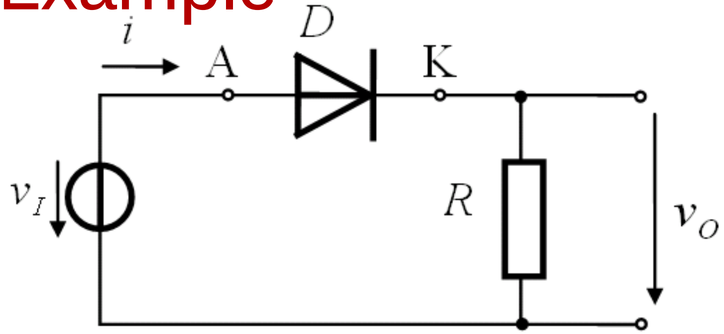


$$\boxed{v_O = i_D R = 0} \qquad \boxed{v_O = 0}$$

$$v_D = v_I - v_O \qquad v_D < 0.7 \qquad v_I - v_O < 0.7$$

$$v_I - 0 < 0.7 \qquad \boxed{v_I < 0.7\text{V}}$$

Example

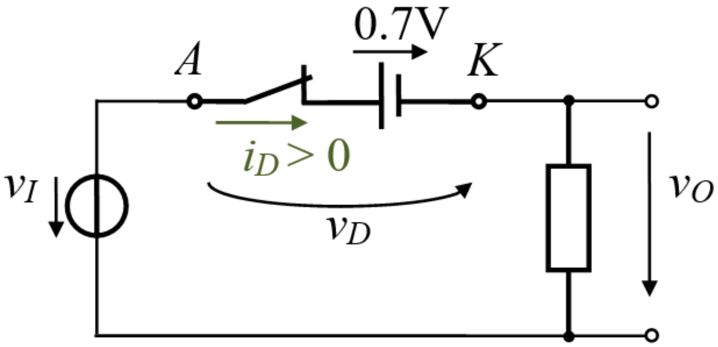


Deduce and plot VTC $v_O(v_I)$

Step 3. Find v_O and the range for v_I by replacing the diode’s equations in the circuit’s equations.

$$\boxed{\begin{array}{l} -v_I + v_D + v_O = 0 \\ v_O = i_D R \end{array}}$$

D – (on) $\left\{ \begin{array}{l} v_D = 0.7\text{V} \\ i_D > 0\text{A} \end{array} \right.$



$$\boxed{-v_I + 0.7 + v_O = 0}$$

$$\boxed{v_O = v_I - 0.7}$$

$$i_D = \frac{v_O}{R}$$

$$\frac{v_O}{R} > 0$$

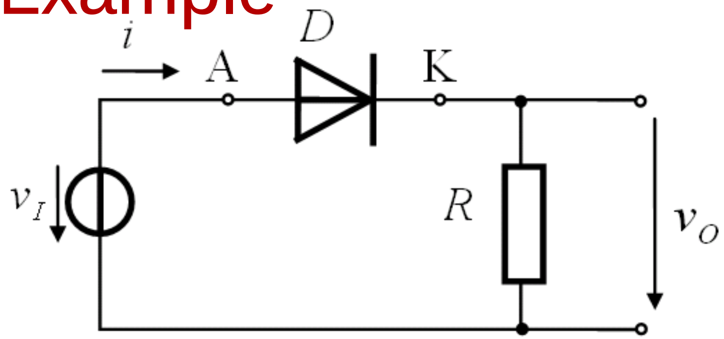
$$v_O > 0$$

$$v_I - 0.7 > 0$$

$$\boxed{v_I > 0.7\text{V}}$$

Two-port DR networks analysis

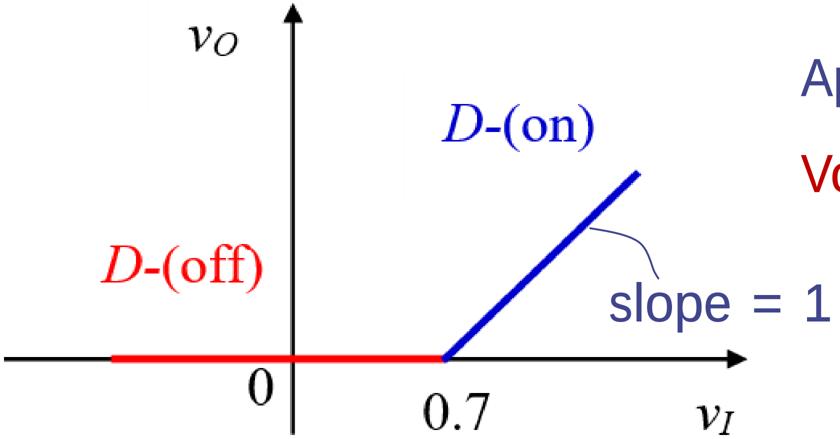
Example



Deduce and plot VTC $v_O(v_I)$

Step 4. Write down the complete expression of VTC $v_O(v_I)$ and plot it, for D-(on) and D-(off).

$$v_O = \begin{cases} 0, & v_I < 0.7\text{V} \\ v_I - 0.7\text{V}, & v_I > 0.7\text{V} \end{cases}$$

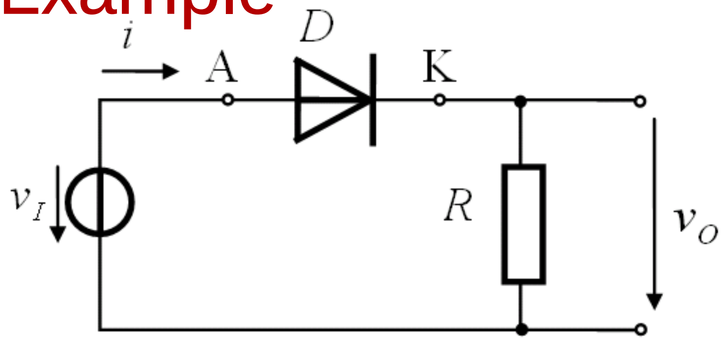


Application:

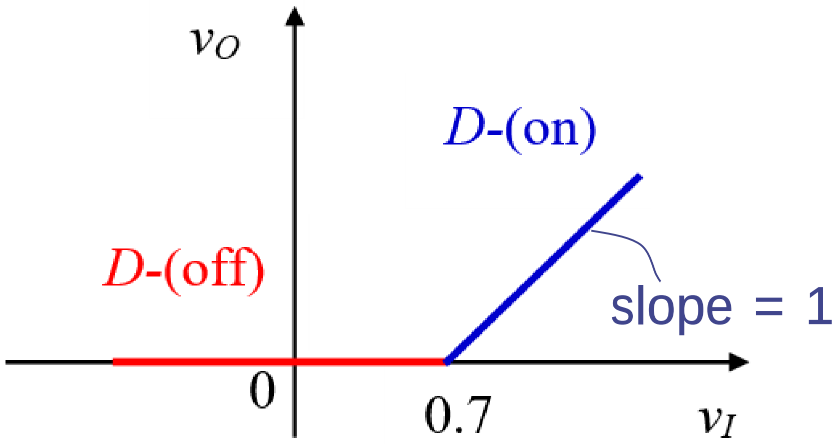
Voltage rectifier

Two-port DR networks analysis

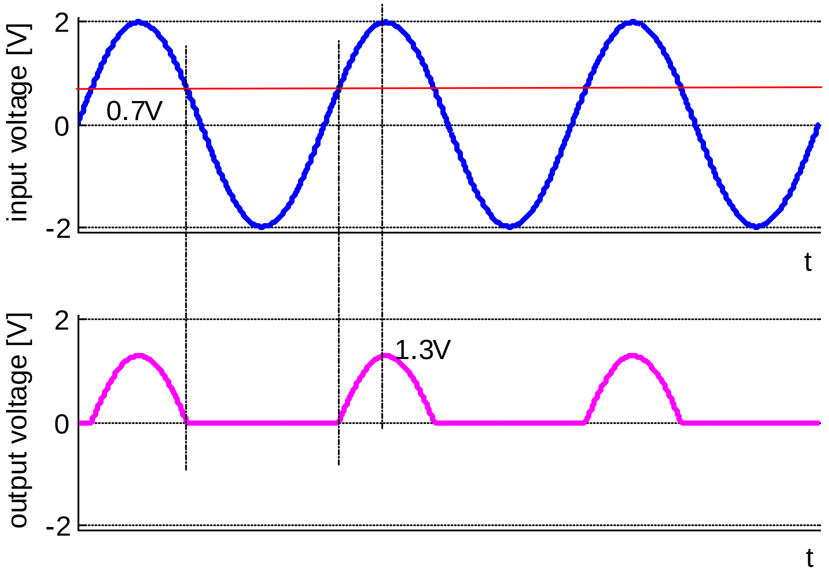
Example



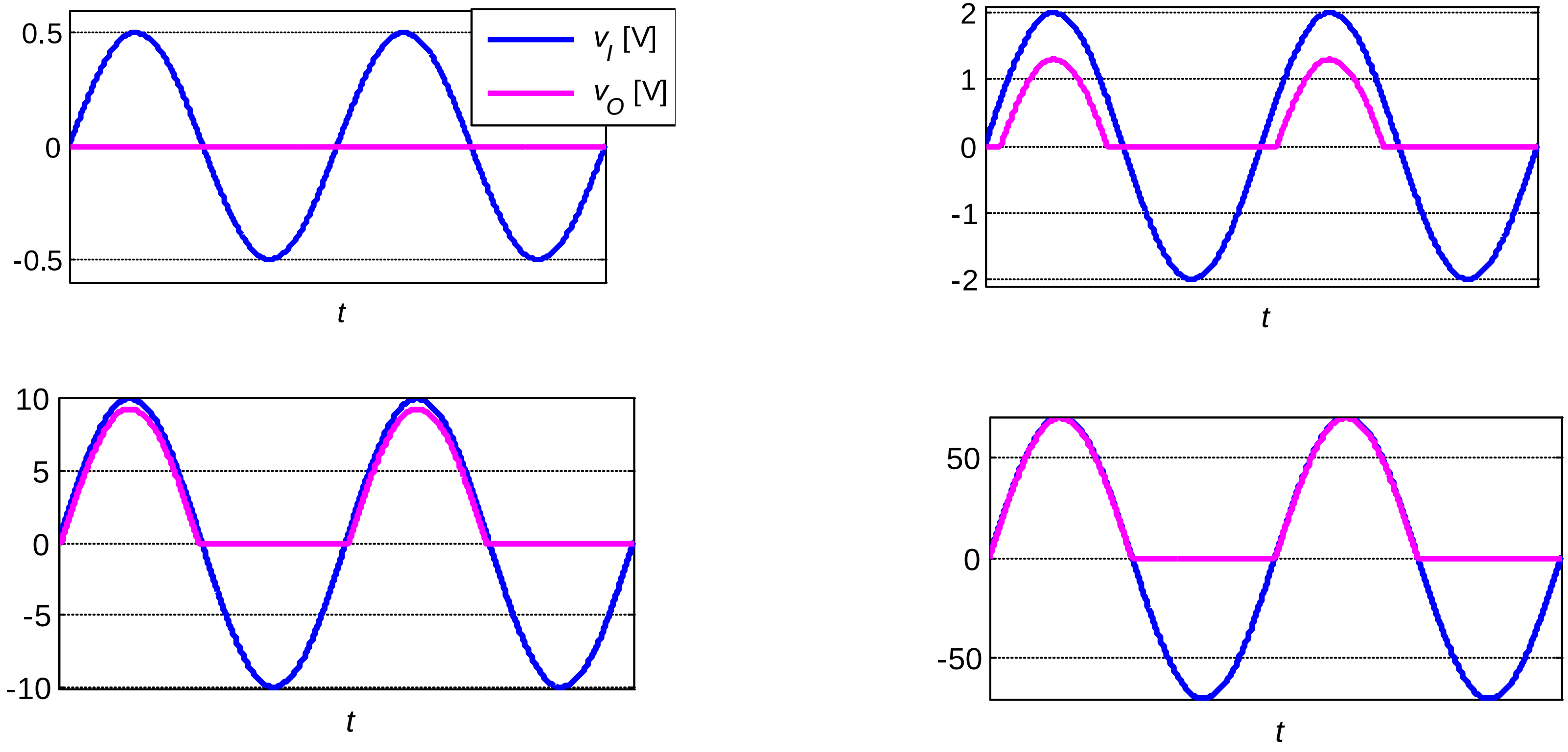
$$v_O = \begin{cases} 0, & v_I < 0.7\text{V} \\ v_I - 0.7\text{V}, & v_I > 0.7\text{V} \end{cases}$$



Waveforms



Influence of V_{Th} and $V_{D,on}$

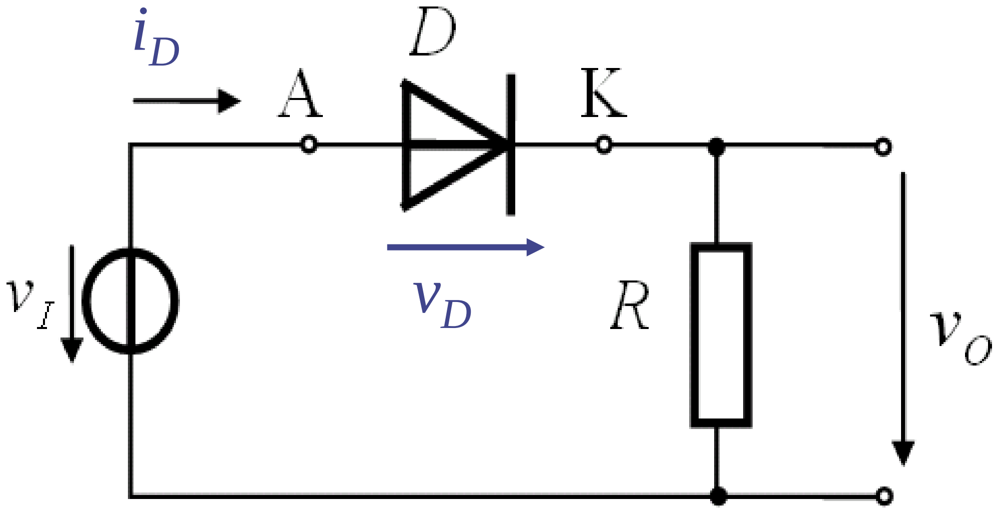


If the input voltage is large enough (**> >** 0.7 V)

- V_{Th} can be considered 0 V
- $V_{D,on}$ can be neglected, meaning that for D – (on), $v_O = v_I$

Two-port DR networks analysis

Example



a) How does the output voltage look like if the input is a sine wave, 3 V amplitude and 2 V offset?

b) What is the peak forward current through diode for R = 2 kΩ?

c) What is the peak reverse voltage V_{DR} across D (v_{DR}=- v_D)?

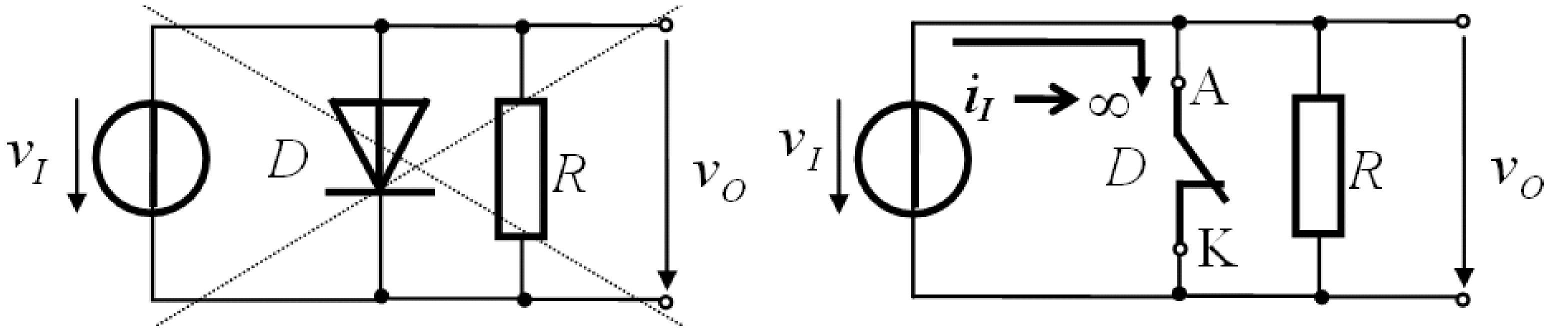
d) Repeat a) and b) if the offset of the input voltage becomes -4 V.

e) Repeat the above points, assuming the diode is reversed in the circuit.

Other series connections

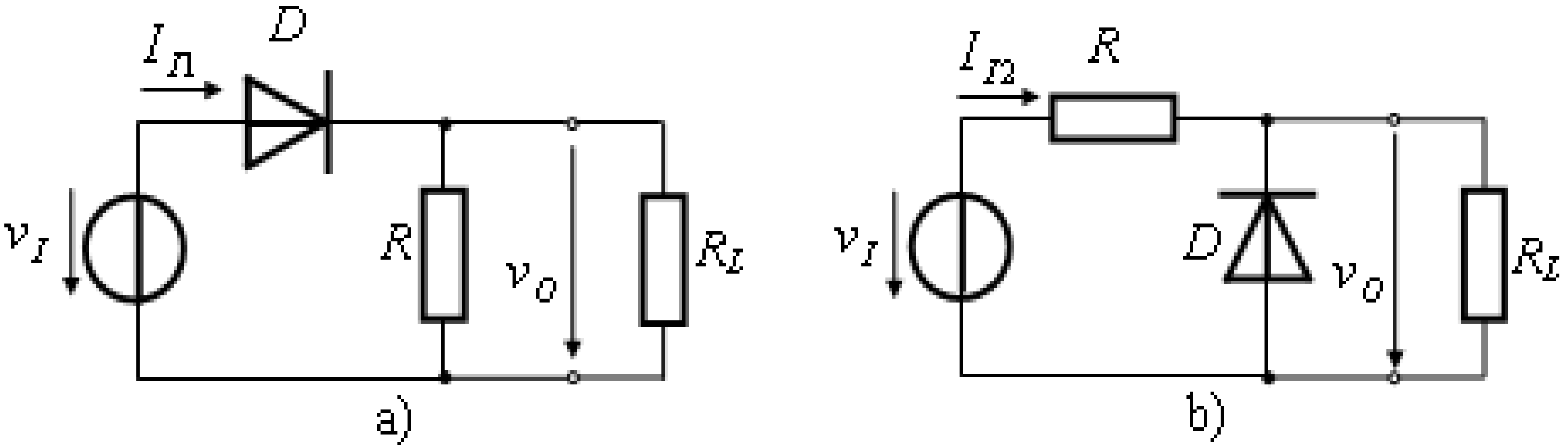
- Reverse the diode
- Change the places of D and R (output voltage collected from D)

!Forbidden connection!



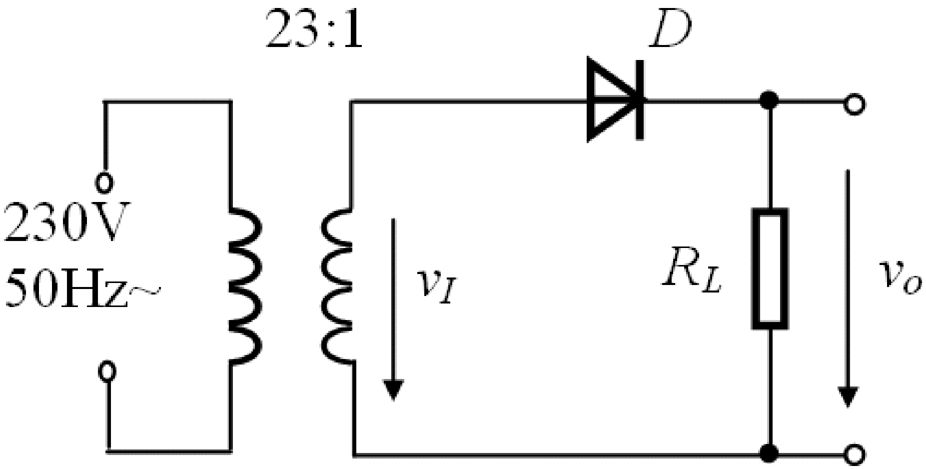
Never connect a voltage source so that during normal operation, the source can be short-circuited.

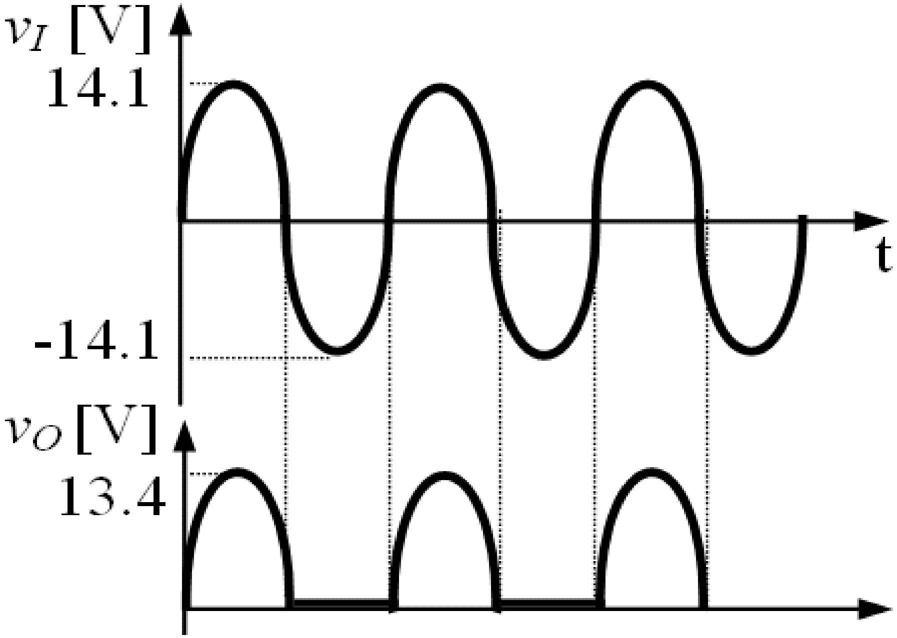
Loaded two-port networks



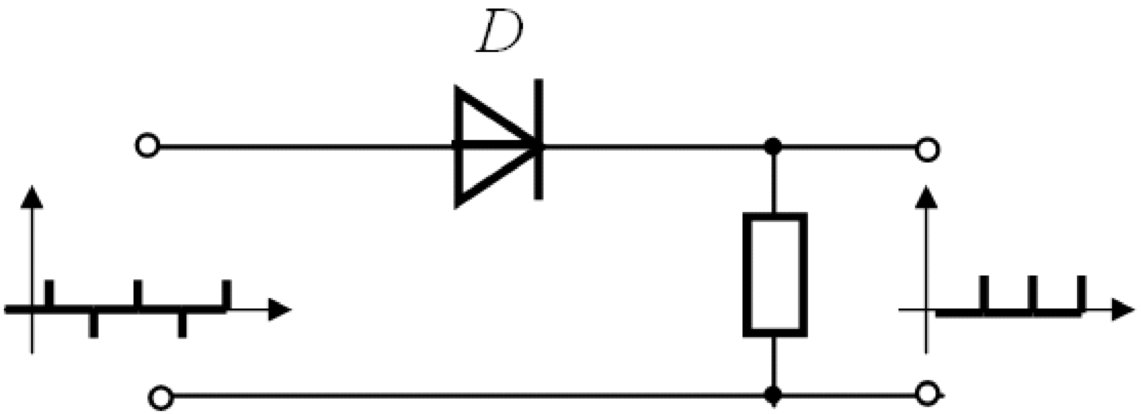
What are the effects of R_L on the VTC and on the output voltage?

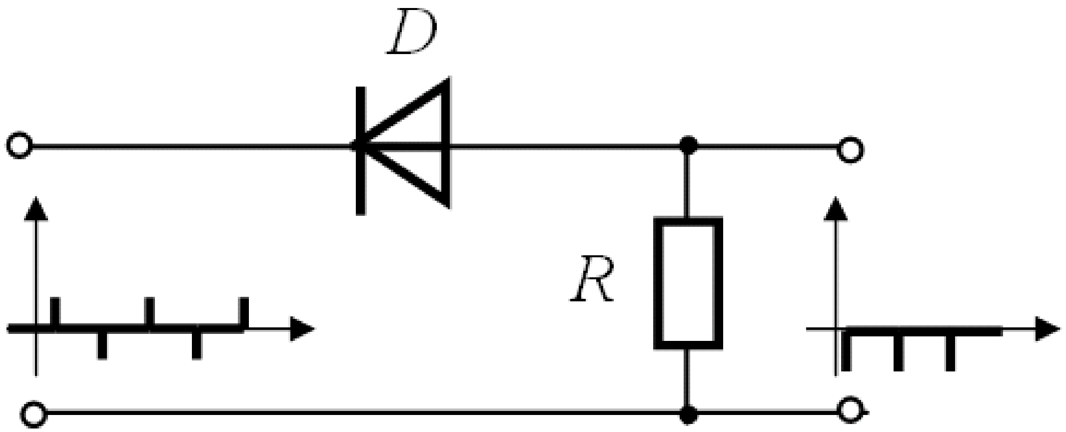
➢ Half-wave rectifier





- Pulses selector

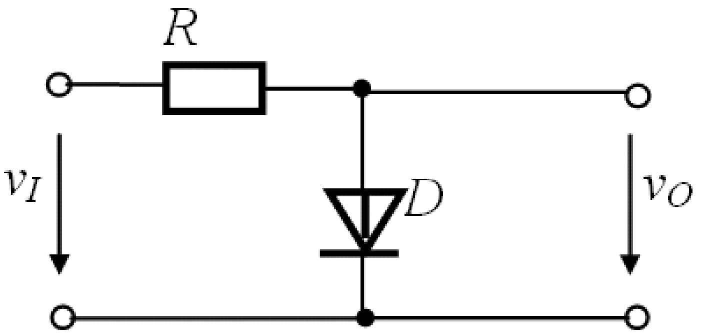




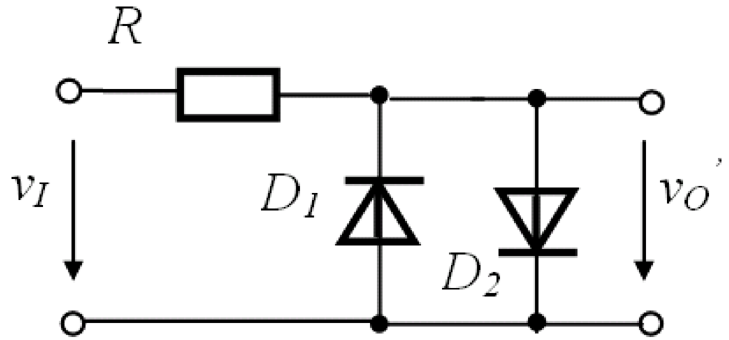
➢ Voltage limiters (clamp networks)

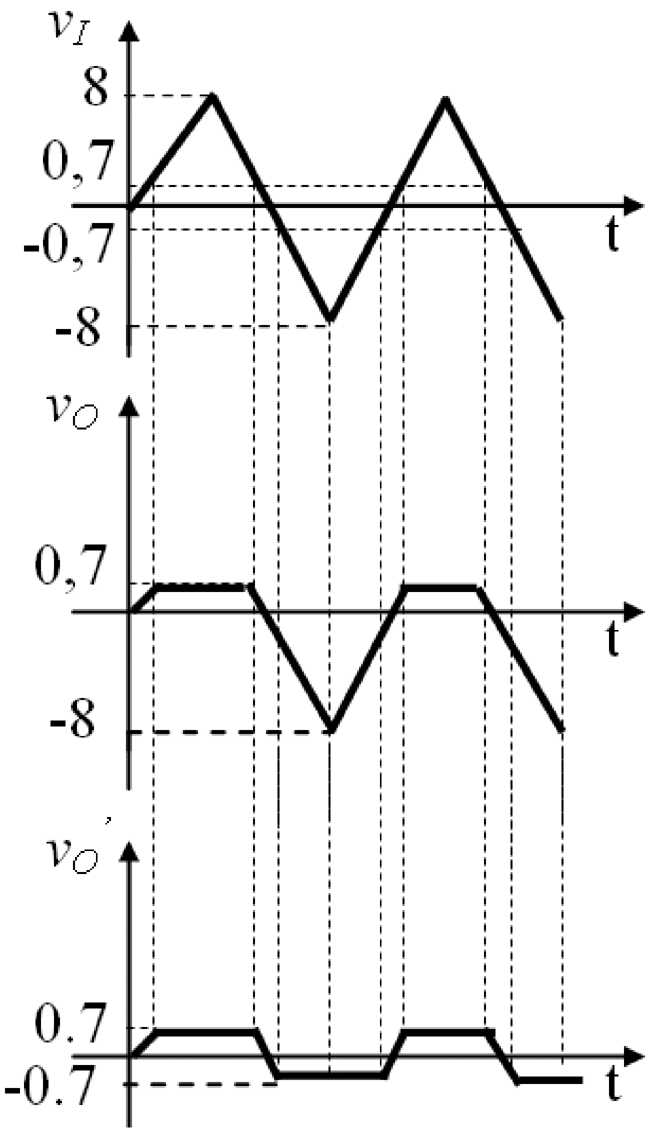
Reverse engineering:
Use the waveforms to deduce and plot VTC v_O (v_I).

simple

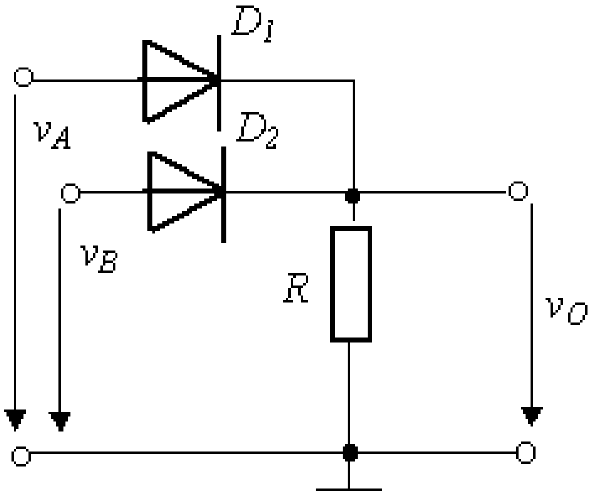


double





➢ Maximum multi-port networks



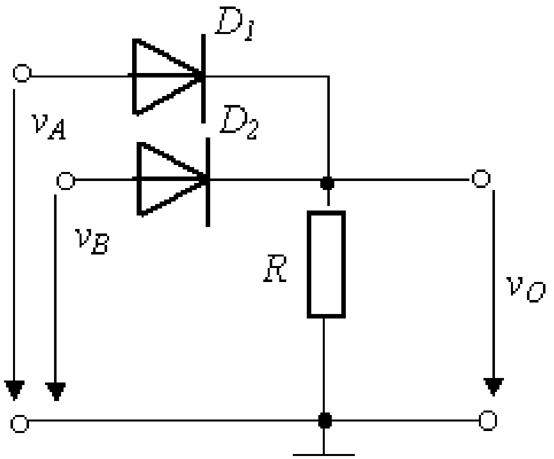
$$\begin{cases} v_A > v_B \\ v_A > 0.7\text{V} \end{cases} \quad D_1-(on),\ D_2-(off);\quad v_O = v_A - 0.7\text{V}$$

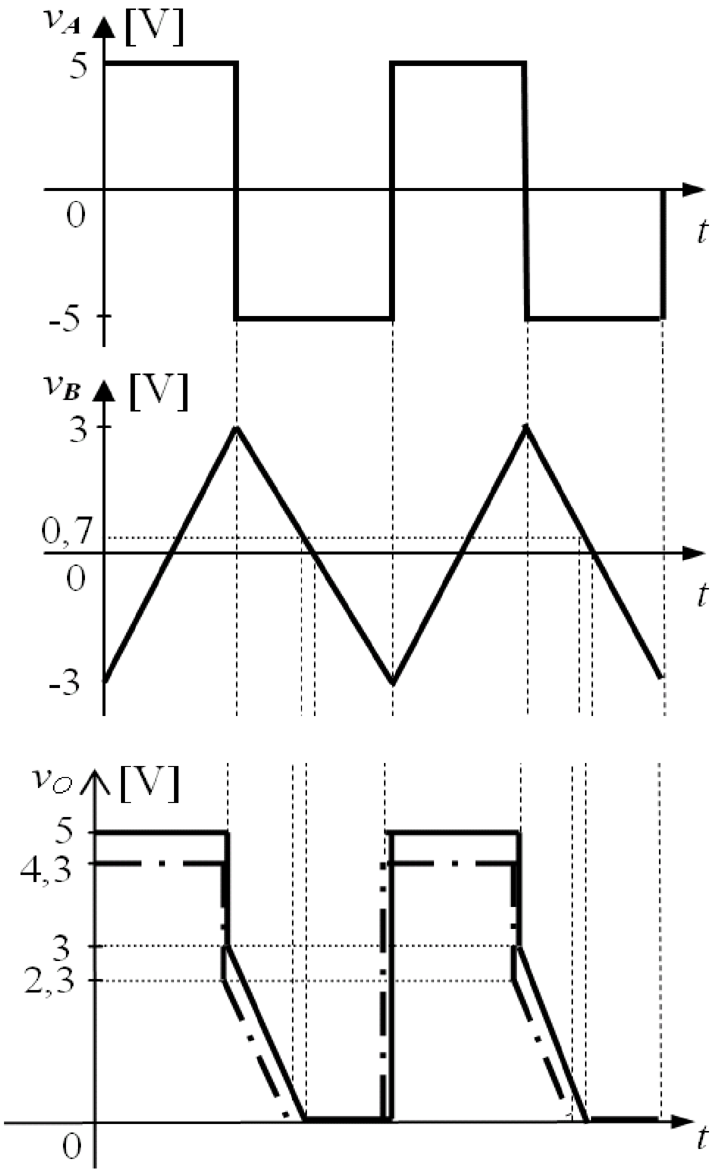
$$\begin{cases} v_B > v_A \\ v_B > 0.7\text{V} \end{cases} \quad D_1-(off),\ D_2-(on);\quad v_O = v_B - 0.7\text{V}$$

$$\begin{cases} v_A < 0.7\text{V} \\ v_B < 0.7\text{V} \end{cases} \quad D_1-(off),\ D_2-(off);\quad v_O = 0$$

$$\boxed{v_O = \max(v_A - 0.7\text{V};\ v_B - 0.7\text{V};\ 0\text{V})}$$

➢ Maximum multi-port networks



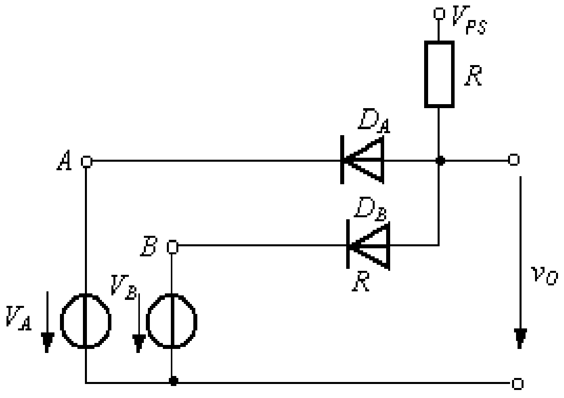


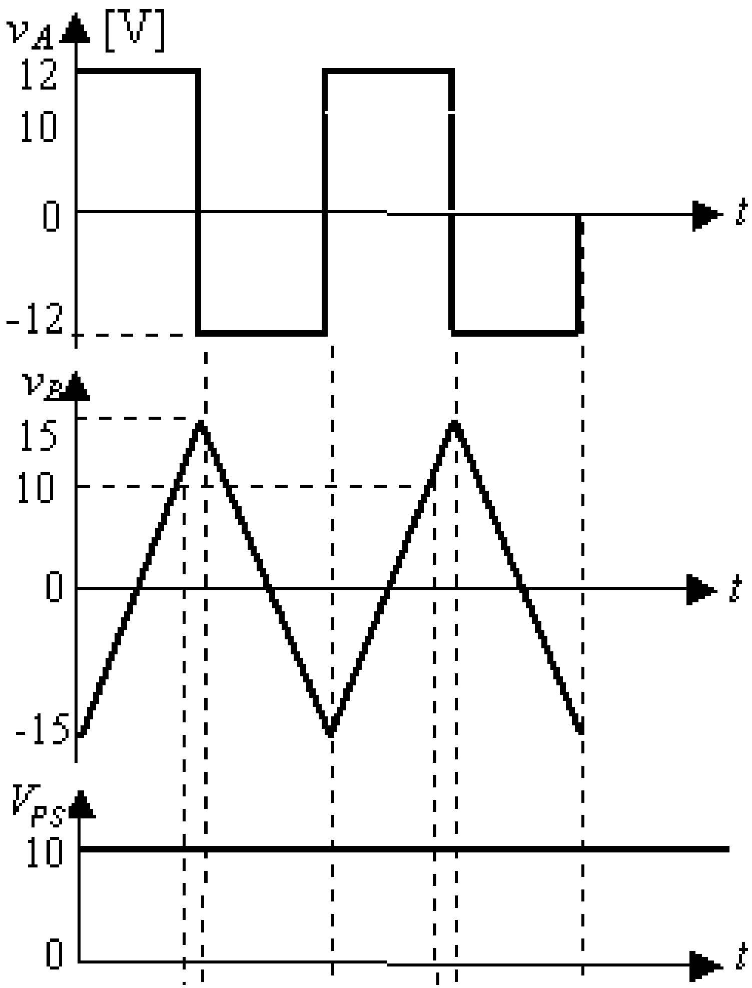
$v_O = \max(v_A - 0.7\ \mathrm{V};\ v_B - 0.7\ \mathrm{V};\ 0)$ — · — · —

$v_O = \max(v_A;\ v_B;\ 0)$ neglecting 0.7 V ———

- What is the peak value of the current through each circuit element if R=5 kΩ?
- What is the range of values for R, if the peak forward current through each diode is 200 mA?

Minimum multi-port networks



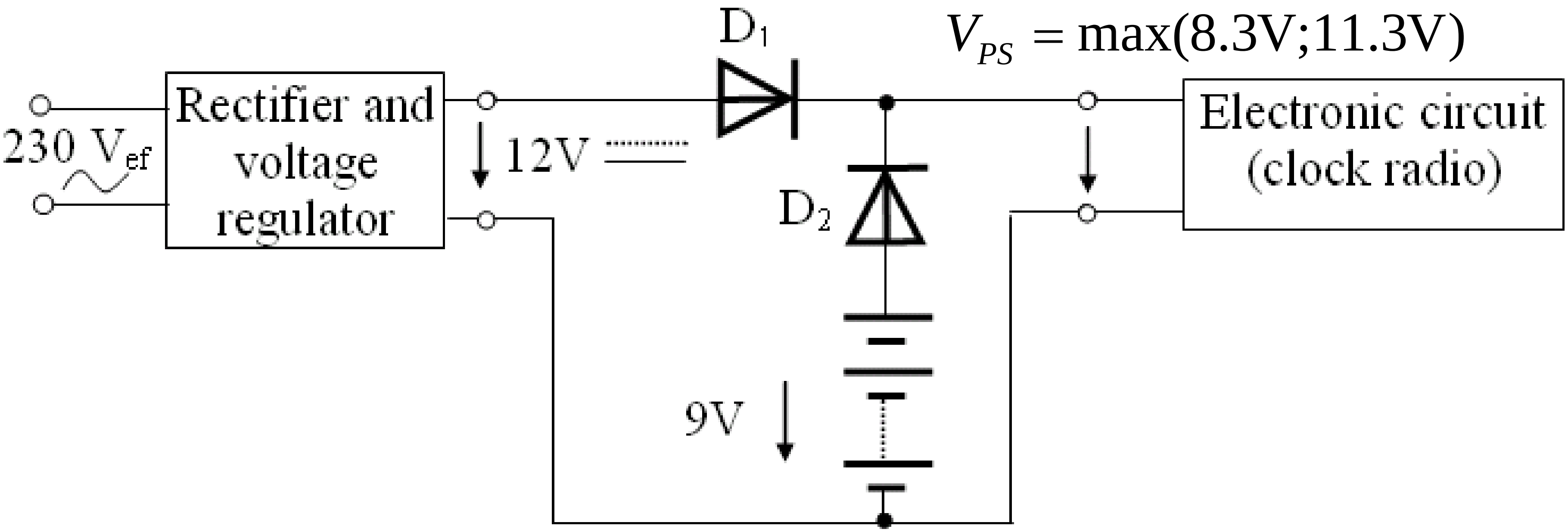


$v_O = \min(v_A + 0.7\text{ V};\ v_B + 0.7\text{ V};\ V_{PS})$

$v_O = \min(v_A;\ v_B;\ V_{PS})$ neglecting 0.7 V

- Plot $v_O(t)$.

- Back-up supply from a 9 V battery



Summary

Although the war is not over, today we won the battle against:

- Two-port DR networks. DR switching circuits.
- Voltage transfer characteristic (VTC)
- Two-port DR networks analysis
- Applications of two-port DR networks

Next week: Full-wave DR rectifiers. DC switching circuits. DRC rectifiers. LEDs.

To do: Homework 1