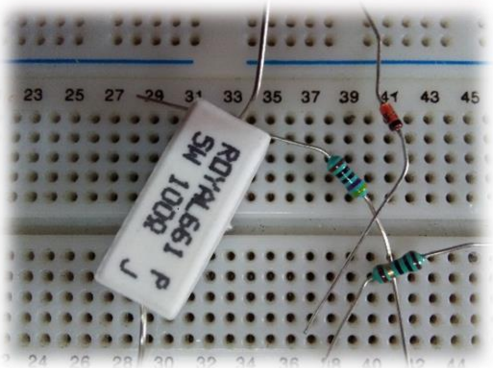
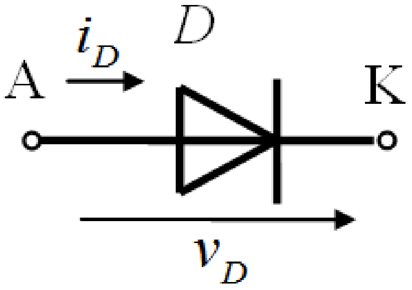
ELECTRONIC DEVICES

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

C3 – Multi-port DR circuits. DC switching circuits.



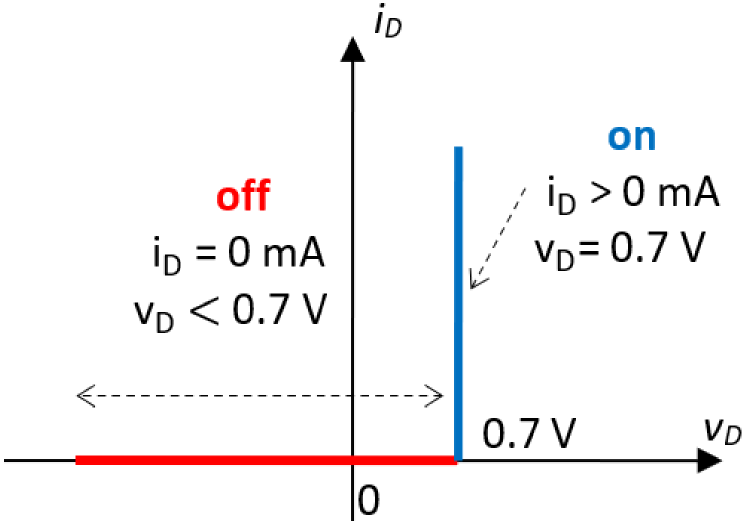
Previously on ED (C2):



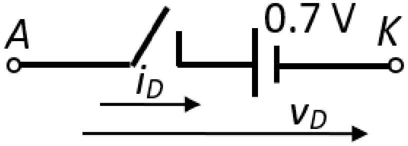
Exponential model

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

Constant voltage drop model

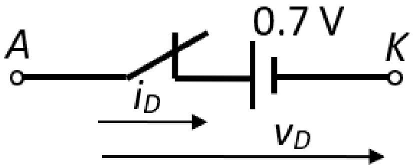


D – (off)



$v_D < 0.7$ V
$i_D = 0$ mA

D – (on)



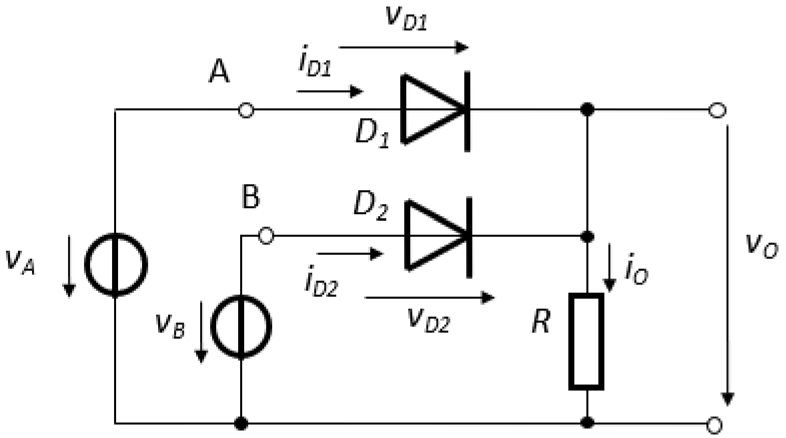
$v_D = 0.7$ V
$i_D > 0$ mA

Contents

- Multi-port DR circuits
  - Maximum multi-port networks
  - Minimum multi-port networks
- Two-port DC switching circuits
  - Positive/negative peak detector
  - Translation networks
  - Voltage doubler

Multi-port DR circuits

Maximum multi-port networks



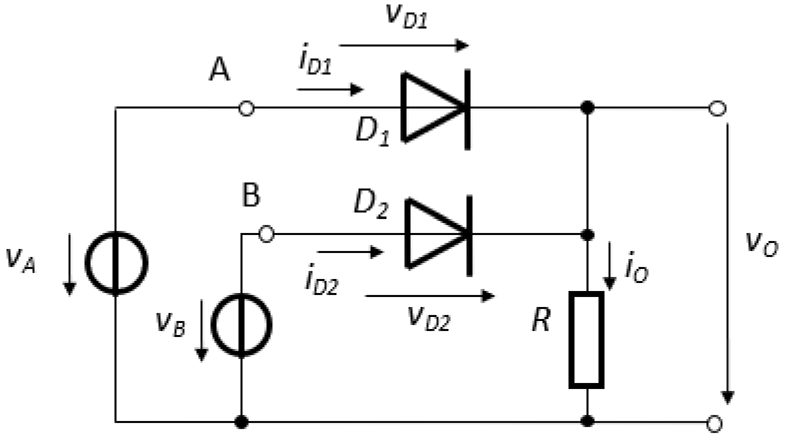
$$\begin{cases} v_A > v_B \\ v_A > 0.7\text{V} \end{cases} \quad D_1-(on),\ D_2-(off);\quad v_O = v_A - 0.7\text{V}$$

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

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

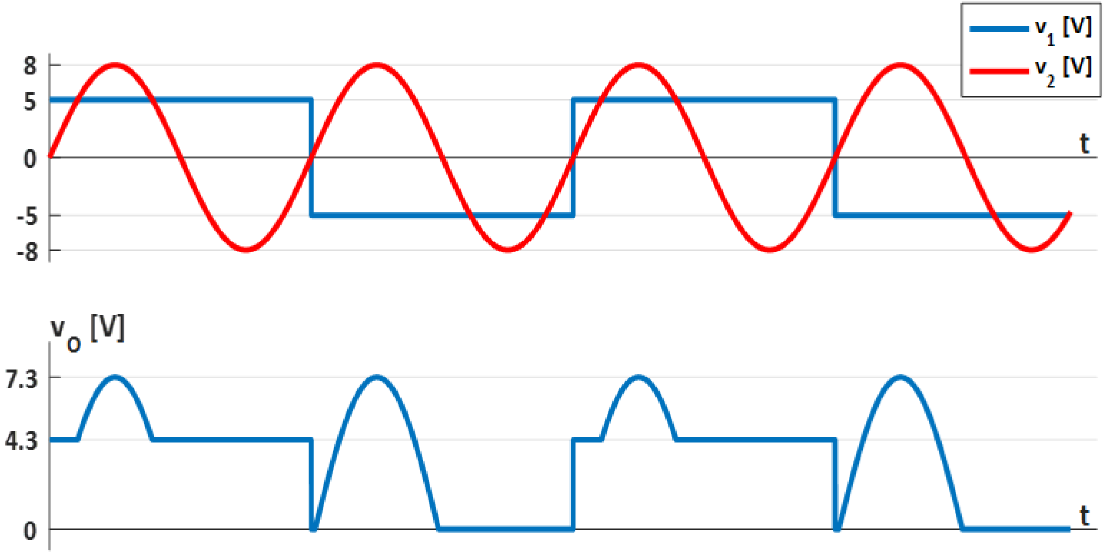
v_O= max(v_A – 0.7 V; v_B – 0.7 V; 0)

➢ Maximum multi-port networks



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

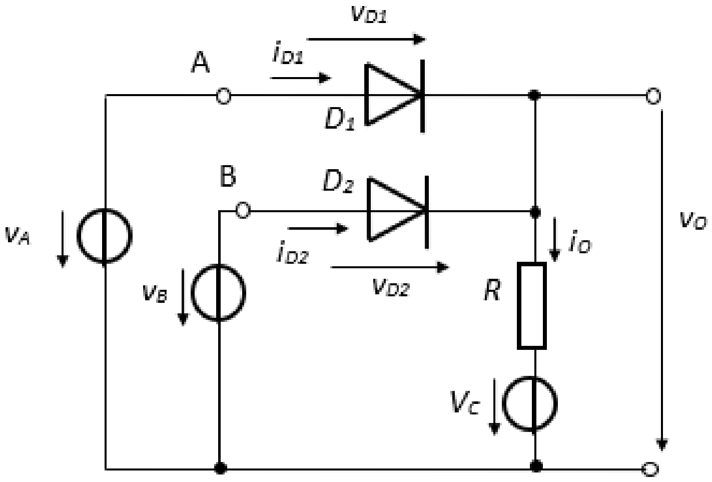
$v_O = \max(v_A; v_B; 0)$ neglecting 0.7 V



- 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 20 mA?

Multi-port DR circuits

➢ Maximum multi-port networks

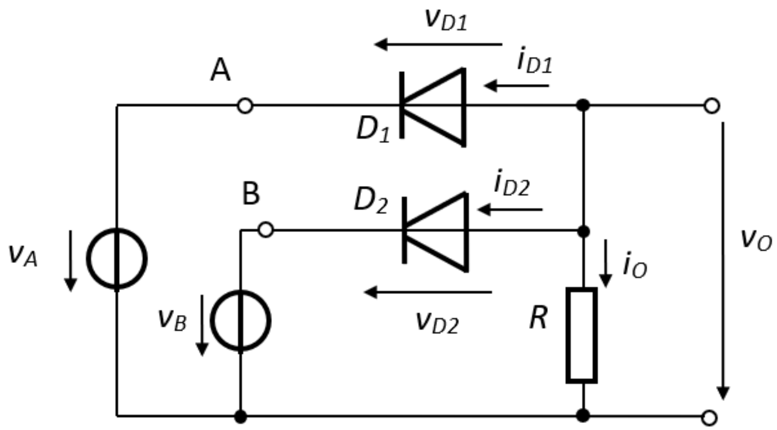


$v_O = \max(v_A - 0.7\text{ V}; v_B - 0.7\text{ V}; V_C)$

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

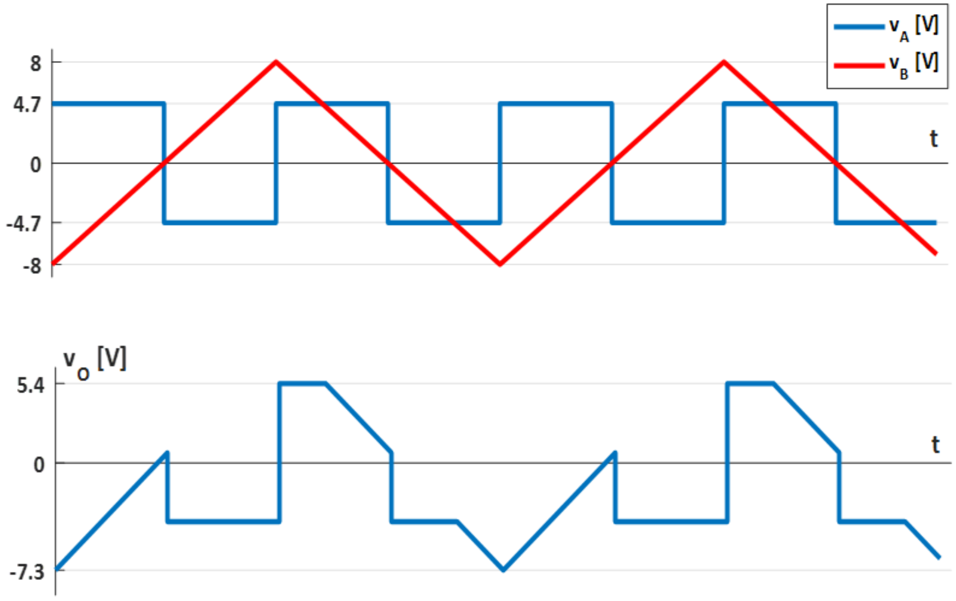
Plot $v_A(t)$, $v_B(t)$ and $v_O(t)$ for if $v_A(t) = 5\sin\omega t$, $v_B(t) = -3\sin\omega t$, $V_C = 4$ V.

➢ Minimum multi-port networks

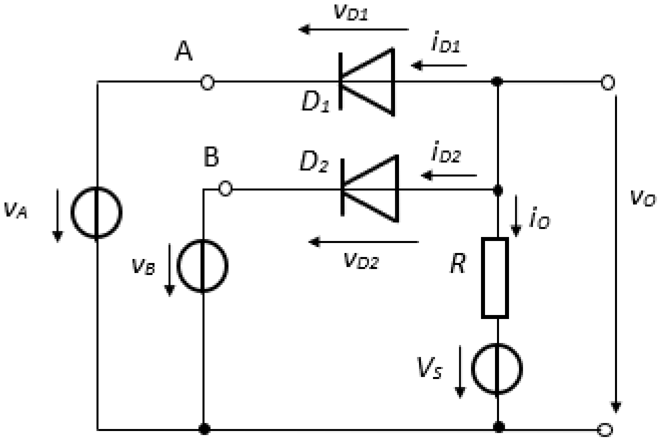


v_O= min(v_A+ 0.7 V; v_B+ 0.7 V; 0)

v_O= min(v_A; v_B; 0) neglecting 0.7 V



Minimum multi-port networks



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

$v_O = \min(v_A; v_B; V_S)$ neglecting 0.7 V

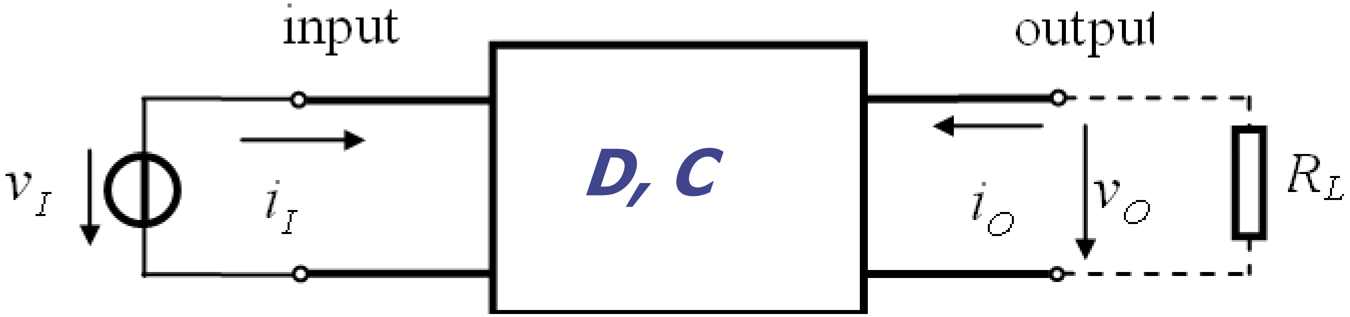
Plot $v_A(t)$, $v_B(t)$ and $v_O(t)$ for if $v_A(t) = 5\sin\omega t$, $v_B(t) = -3\sin\omega t$, $V_S = 4$ V.

Two-port DC networks

Preamble

The steady-state properties (i.e. the VTC) of two-port DC networks are of no interest in applications.

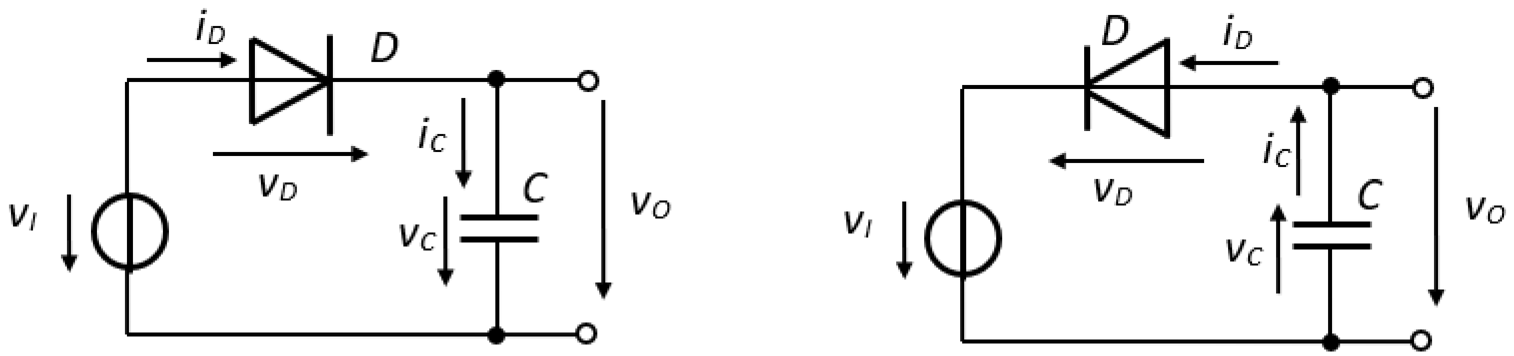
The focus is on the time-domain behavior – how does v_O look for variable v_I?



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

Two-port DC networks

➢ Temporal extreme two-port DC networks



Output voltage – measured across the capacitor

Based on the states of the diodes, there are two possible cases:

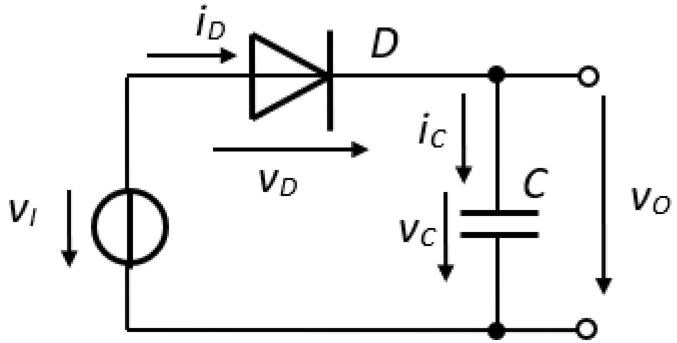
1. If v_D tends to be > 0.7 V, D – (on)

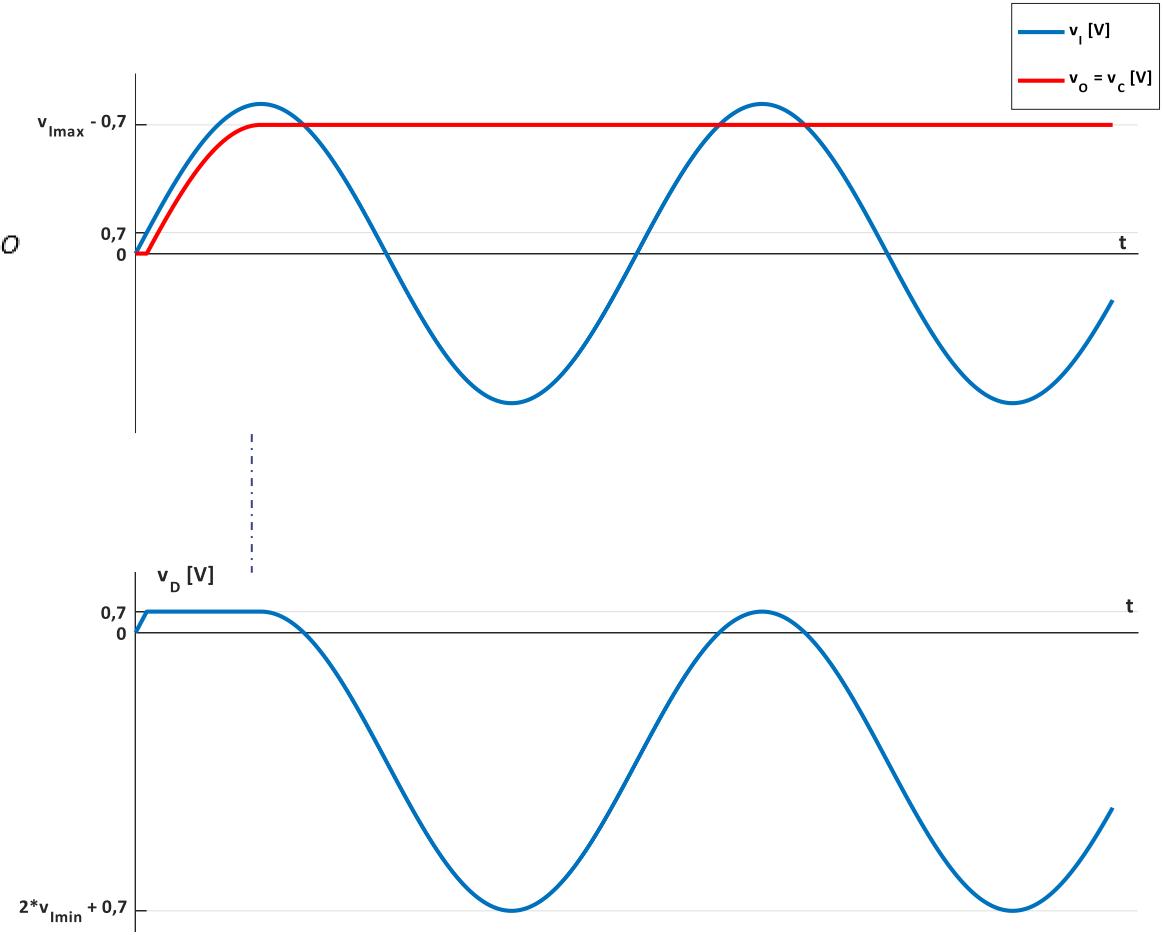
$v_D = 0.7$ V, $i_C(t) > 0$, $v_C(t)$ increases (C charges)

2. If $v_D < 0.7$ V, D – (off)

$i_C(t)=0$ $v_C(t)=$ constant

➢ Temporal extreme two-port DC networks





$$v_D(t) = v_I(t) - v_O(t)$$

$$v_O(t) = v_C(t)$$

$$v_D = 0.7 \text{ V}$$

$$v_C(t) = v_I(t) - 0.7 \text{ V}$$

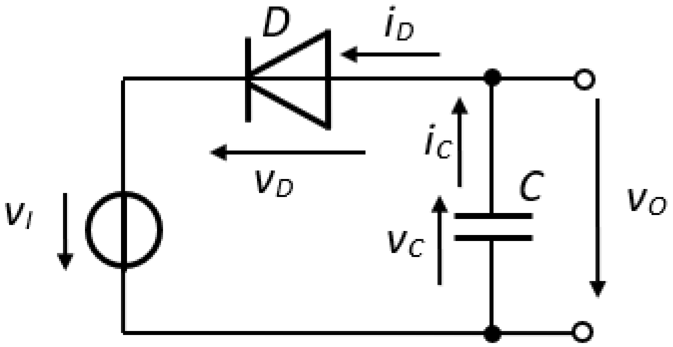
$$v_{Cmax} = v_{Imax} - 0.7 \text{ V} > 0$$

$$v_D(t) = v_I(t) - v_{Cmax} < 0.7 \text{ V}$$

$$v_O(t) = v_{Cmax} = \text{constant}$$

Application: Positive peak detector

➢ Temporal extreme two-port DC networks



$v_D(t) = v_O(t) - v_I(t)$

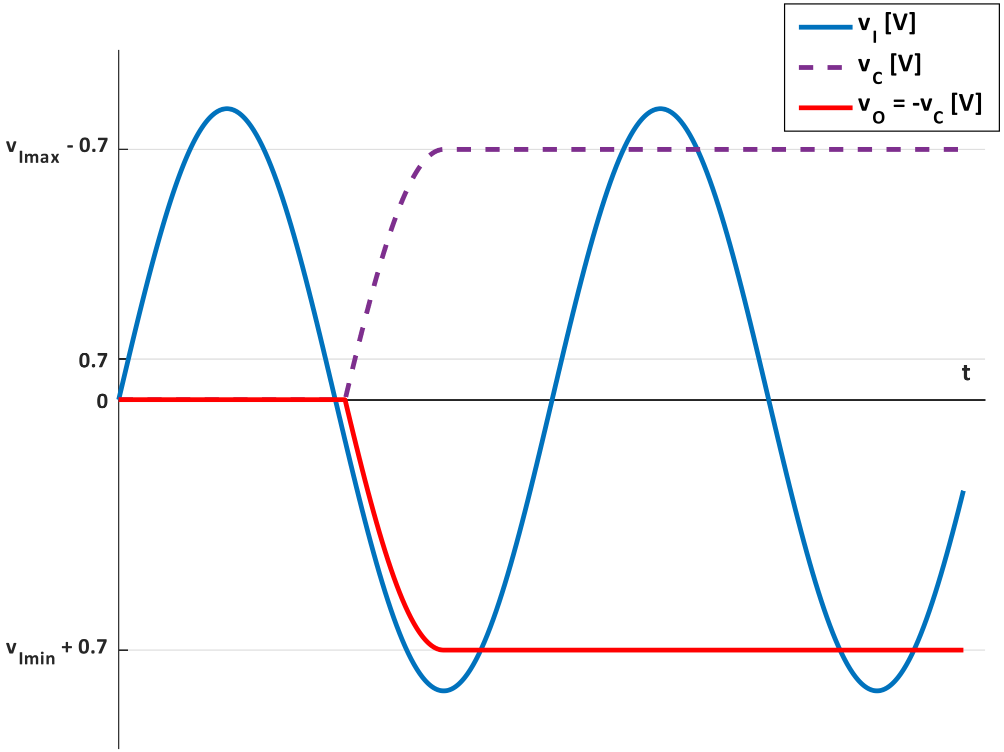
$v_O(t) = -v_C(t)$

$v_D = 0.7$ V

$v_C(t) = -v_I(t) - 0.7$ V

$v_{Cmax} = -v_{Imin} - 0.7\text{ V} > 0$

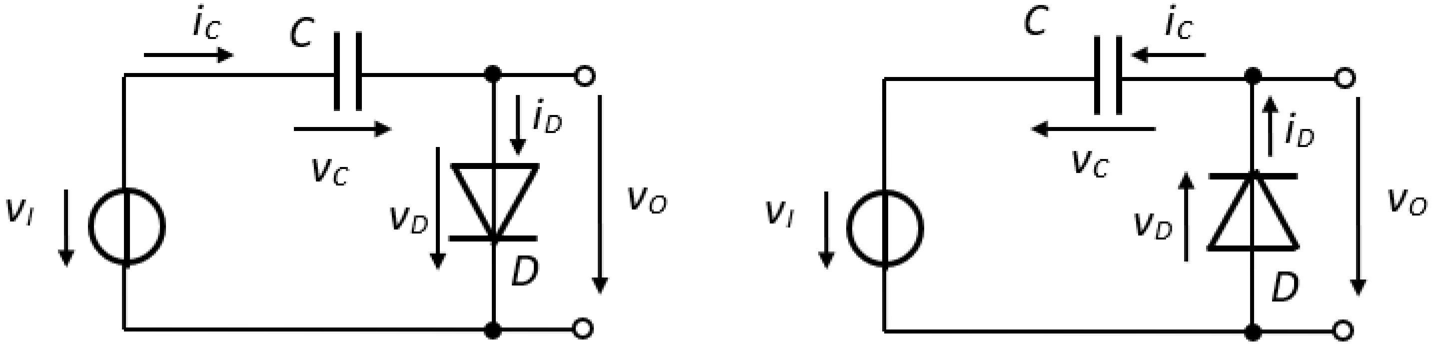
$v_O(t) = -v_{Cmax} = \text{constant}$



Application: Negative peak detector

Two-port DC networks

Translation two-port DC networks



Output voltage – measured across the diode

Based on the states of the diodes, there are two possible cases:

1. If v_D tends to be > 0.7 V, D – (on)

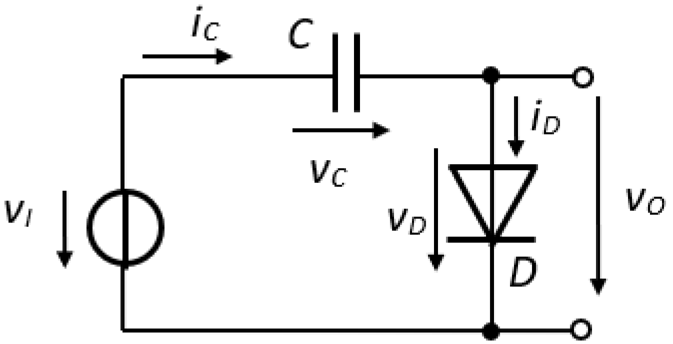
$v_D = 0.7$ V, $i_C(t) > 0$, $v_C(t)$ increases (C charges)

2. If $v_D < 0.7$ V, D – (off)

$i_C(t)=0$ $v_C(t) =$ constant

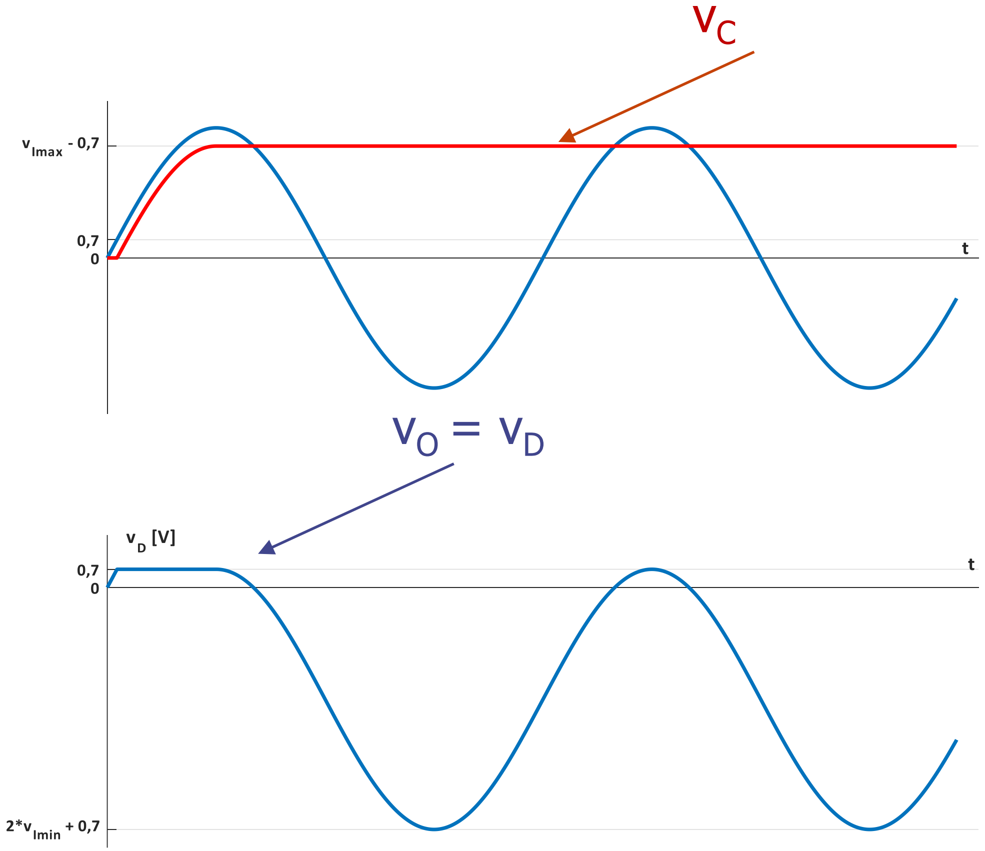
Two-port DC networks

Translation two-port DC networks



$$v_D(t) = v_I(t) - v_C(t)$$

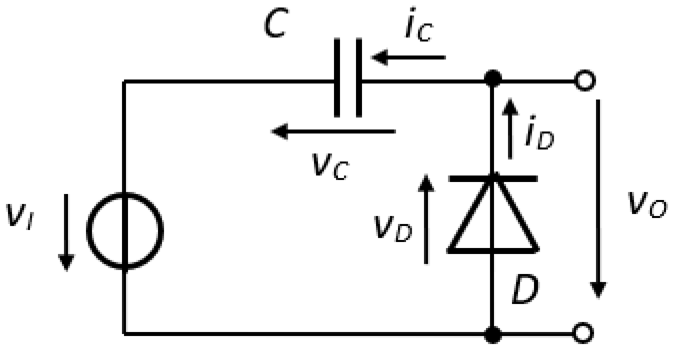
$$v_O(t) = v_D(t) \leq 0.7\ \text{V}$$

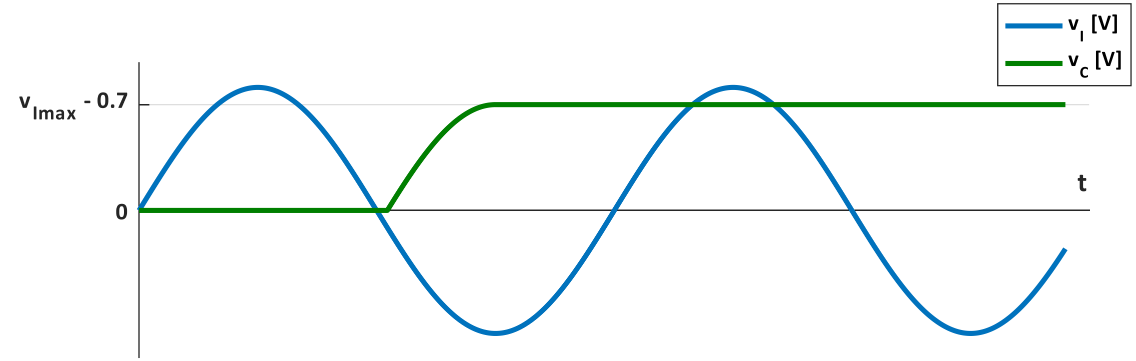


Application:

Translation towards negative values (downward)

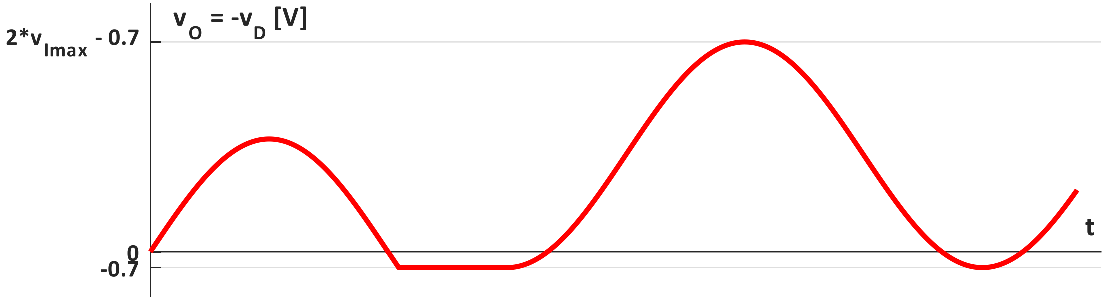
➢ Translation two-port DC networks





$$v_D(t) + v_I(t) + v_C(t) = 0$$

$$v_O(t) = -v_D(t) \geq -0.7\text{ V}$$



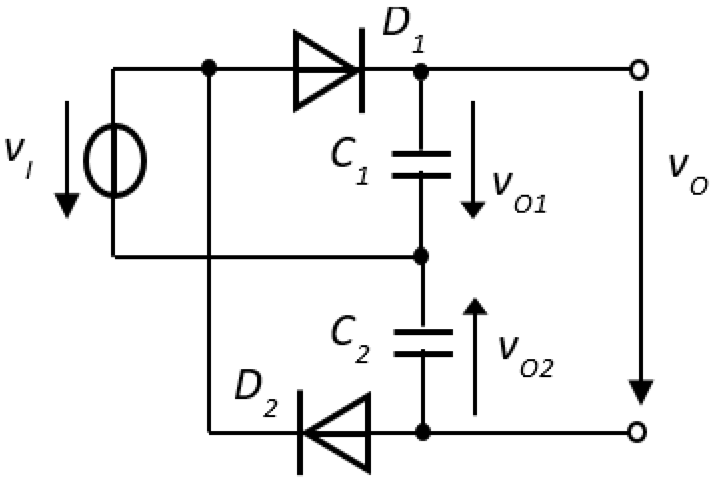
Application:

Translation towards positive values (upward)

Voltage doubler

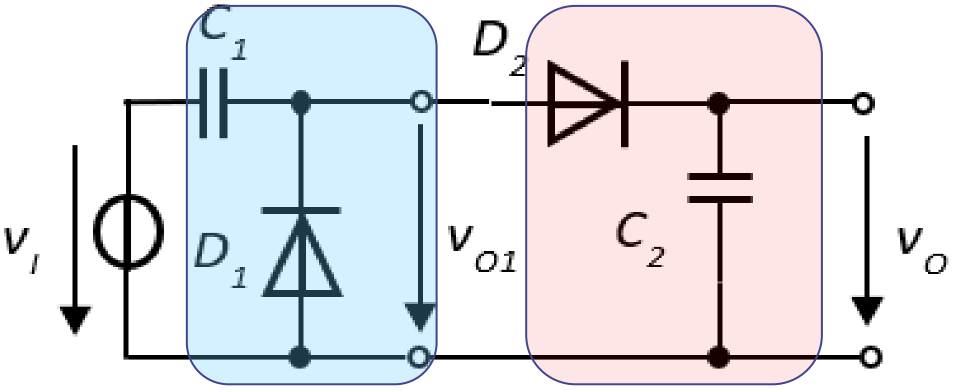
- variable (ac) input voltage
- dc output voltage
- output voltage is (almost) twice the amplitude of the input voltage

❑ **Solution 1:** series connection of a positive peak detector and a negative peak detector (common input)



➢ Voltage doubler

❑ **Solution 2:** chain connection of an upward translation circuit and a positive peak detector



Translation toward positive values

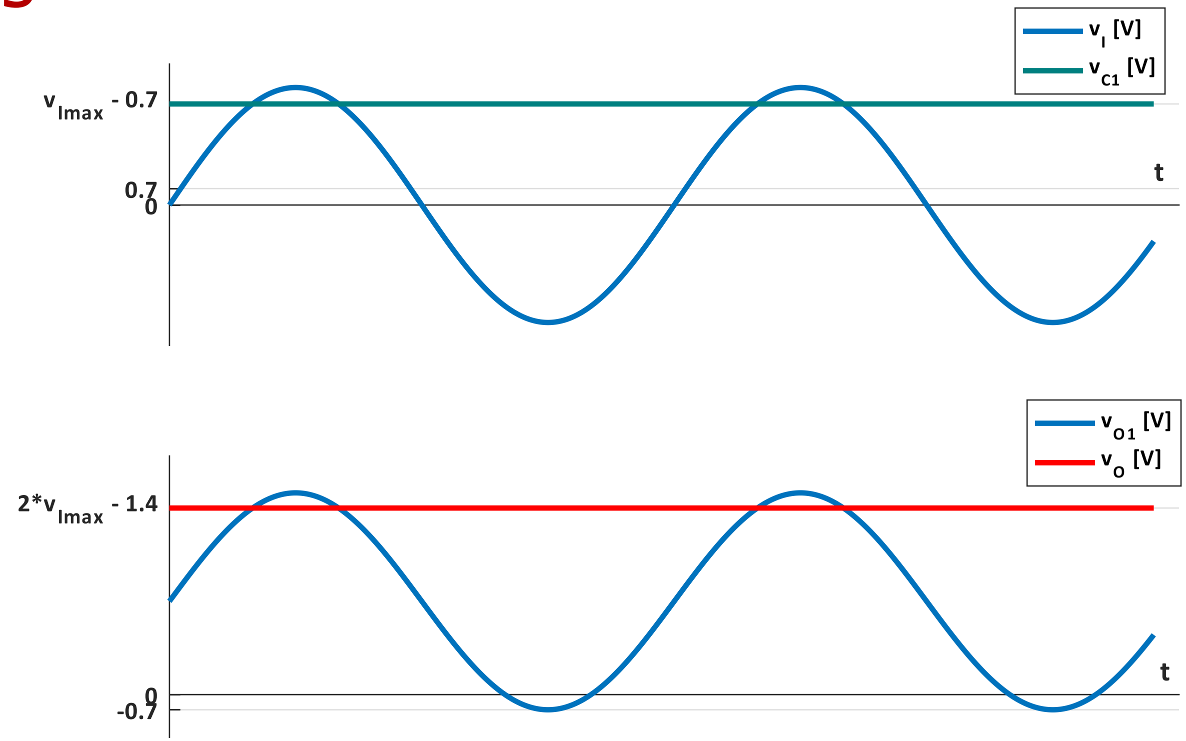
Positive peak detector

$$v_{O1}(t) = v_I(t) + v_{Cmax}$$
$$v_{O1max} = v_{Imax} + v_{Imax} - 0.7\ \text{V}$$

$$v_O = v_{O1max} - 0.7\ \text{V}$$
$$v_O = 2 \cdot v_{Imax} - 1.4\ \text{V} = \text{constant}$$

Two-port DC networks

Voltage doubler



steady-state waveforms

Summary

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

- Multi-port DR circuits
    - Maximum multi-port networks
    - Minimum multi-port networks
- Two-port DC switching circuits
    - Positive/negative peak detector
    - Translation networks
    - Voltage doubler

Next week: DR rectifiers. DRC rectifiers. LEDs. Photodiodes.