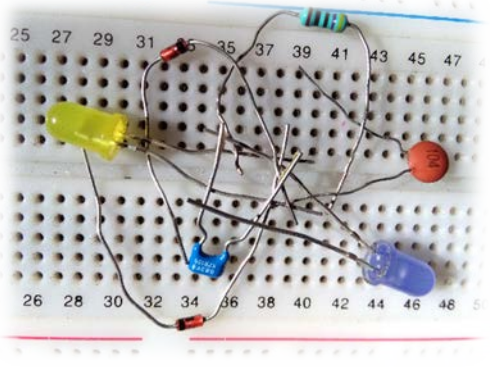
# ELECTRONIC DEVICES

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

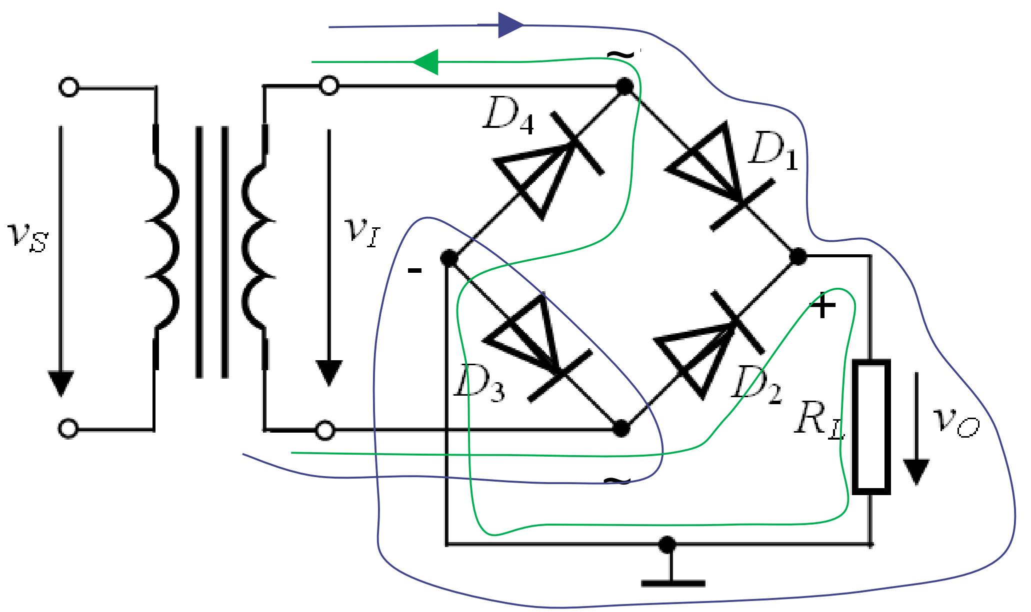
# C4 – Full-wave DR rectifiers. DC switching circuits. DRC rectifiers. LEDs.

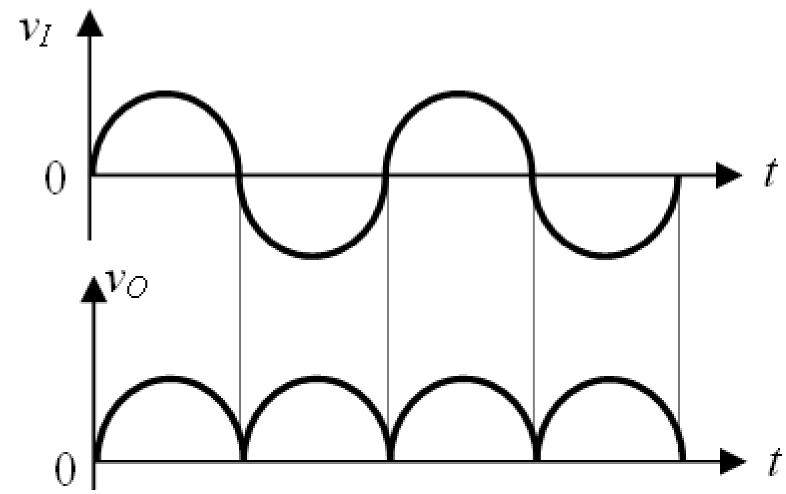


# Contents

- Full-wave DR rectifiers
- Two-port DC networks
    - Positive/negative peak detector
    - Translation networks
    - Voltage doubler
- DRC rectifiers (power supply filtering)
- LEDs and photodiodes

# ➢ Full-wave rectifier – diode bridge




neglecting 0.7 V

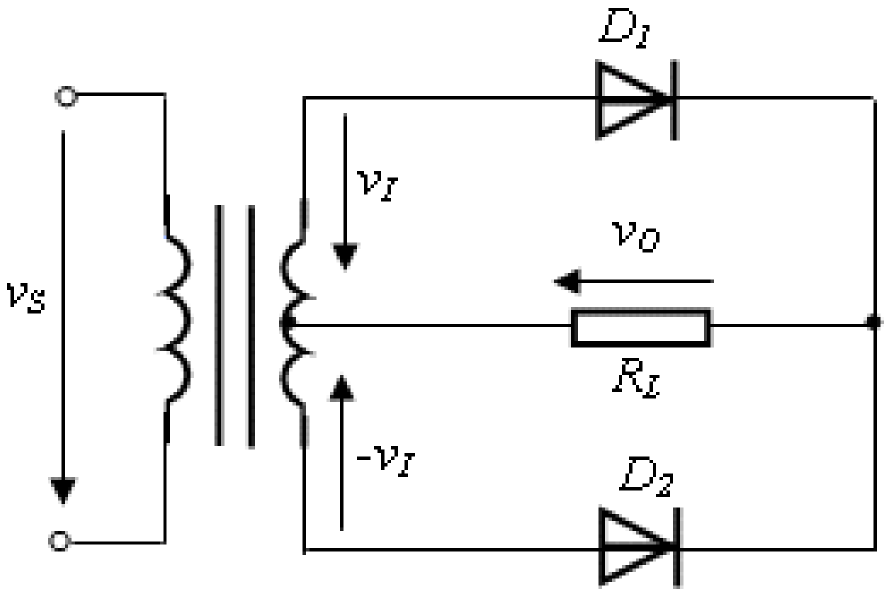
- positive half, $v_I > 0$

$D_1$, $D_3$ – (on) $D_2$, $D_4$ – (off)

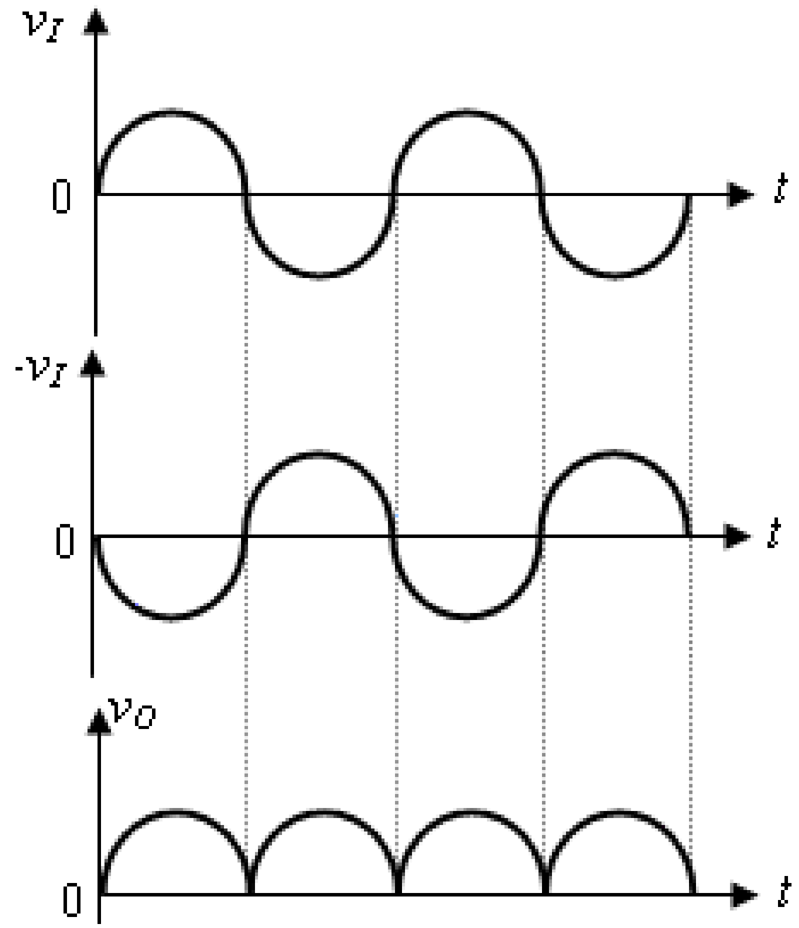
- negative half, $v_I < 0$

$D_1$, $D_3$ – (off) $D_2$, $D_4$ – (on)

# ➢ Full-wave rectifier – center-tapped transformer

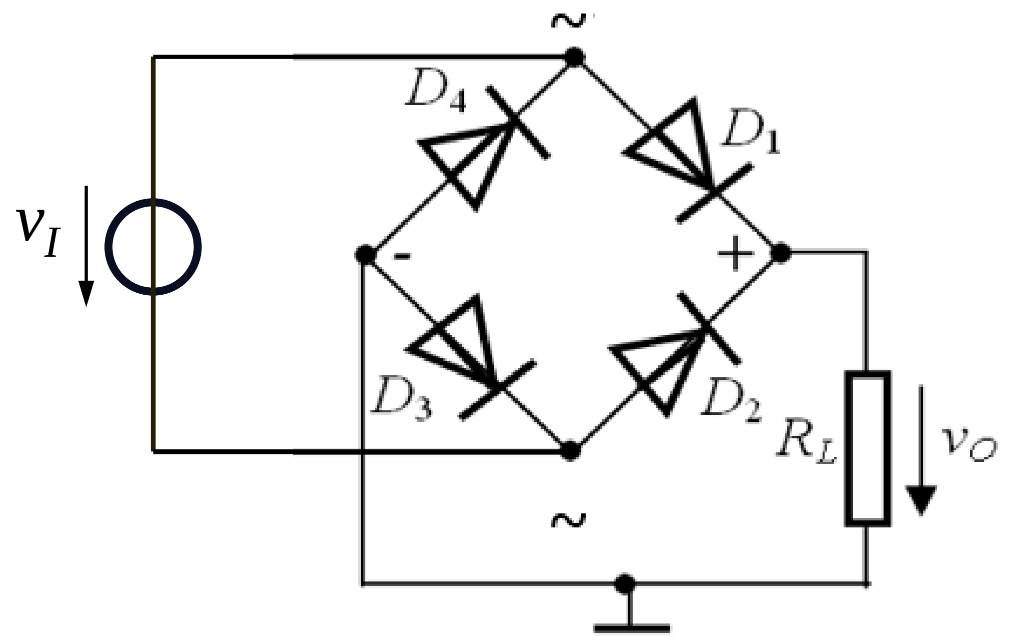



neglecting 0.7 V



# Example

$$v_I(t) = \hat{V}_I \sin \omega t$$




For the circuit in the figure, $R_L$=50Ω. Assume $\hat{V}_I = 7V$.

a) Plot $v_O(t)$ and $i_O(t)$

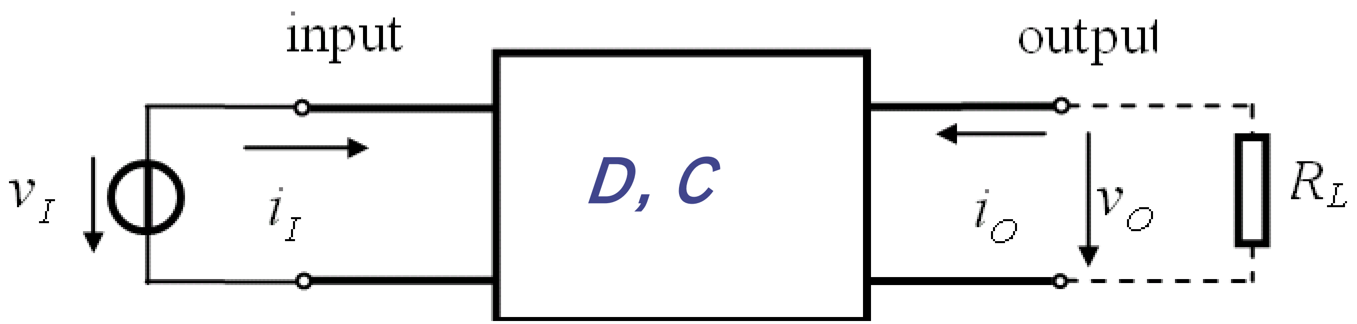
b) Compute the values of the maximum reverse voltage $v_{DR}$ across each diode and the maximum forward current through each diode.

c) Repeat a) and b) assuming $\hat{V}_I = 100V$.

# Preamble

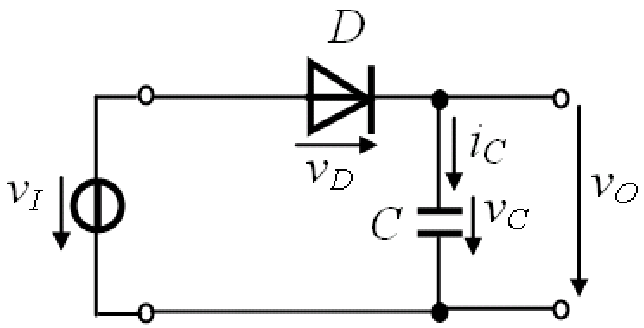
The steady-state properties (i.e. the VTC) of two-port DC networks are of no interest in applications.

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.

# ➢ Temporal extreme two-port DC networks




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

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

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

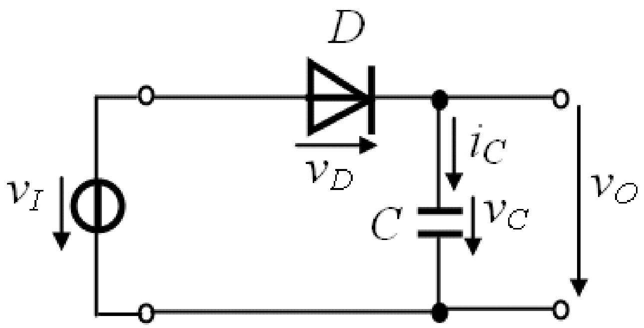
1. If $v_D$ tends to be $> 0.7$ V, $D$ – (on)

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

2. If $v_D < 0.7$ V, $D$ – (off)

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

# ➢ Temporal extreme two-port DC networks

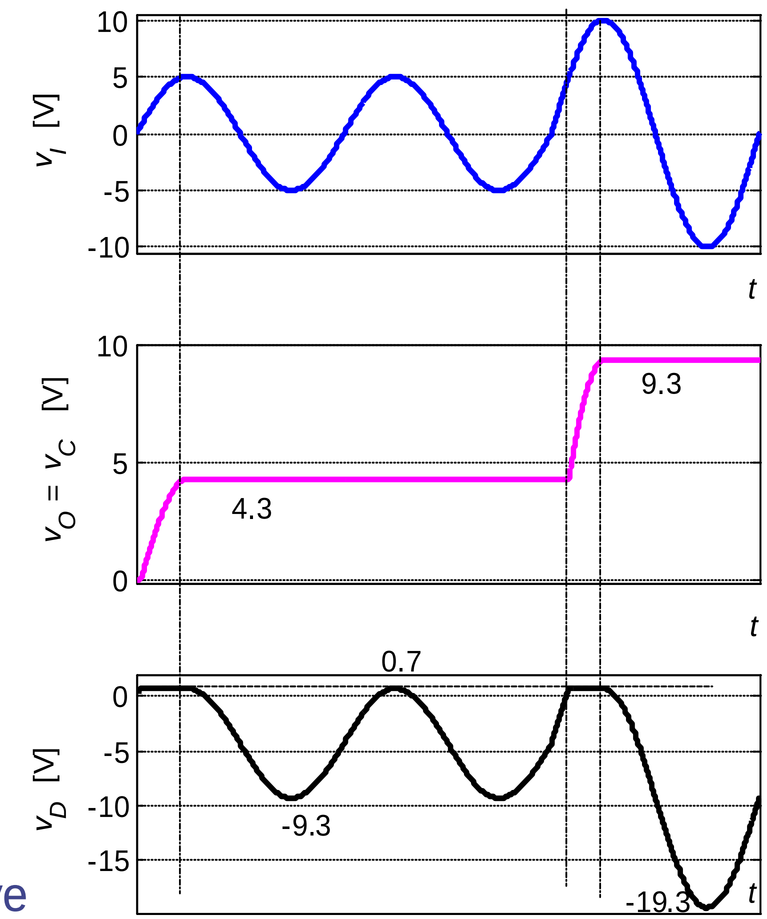



$$v_D(t) = v_I(t) - v_O(t)$$

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

Application:

Positive peak detector

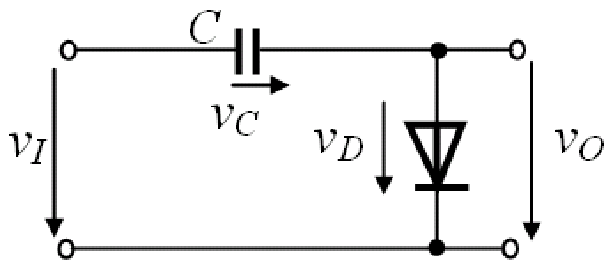



- Plot $v_O(t)$, $v_D(t)$ if $v_I(t)$ is a 6 V amplitude sine wave with a dc component of:

i) 0 V; ii) +2 V; iii) -7 V

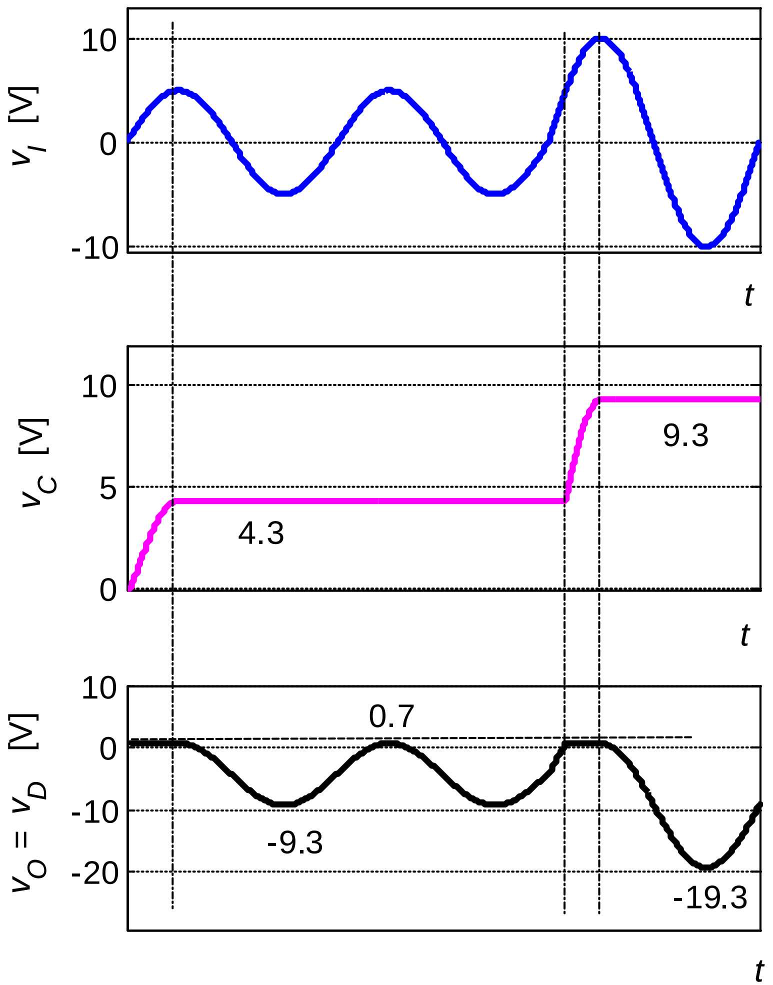
- Change the circuit, in order to obtain a negative peak detector.

# ➢ Translation two-port DC networks




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

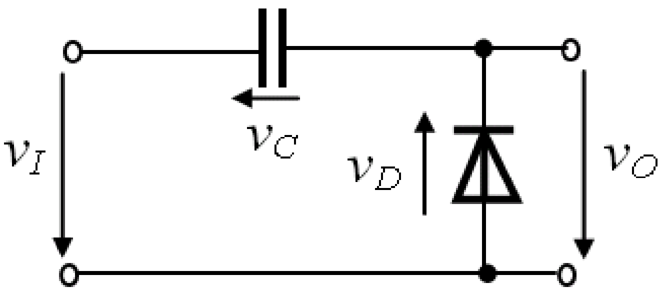
$$v_O(t) = v_D(t)$$




Application:

Translation towards negative values (downward)

# ➢ Translation two-port DC networks

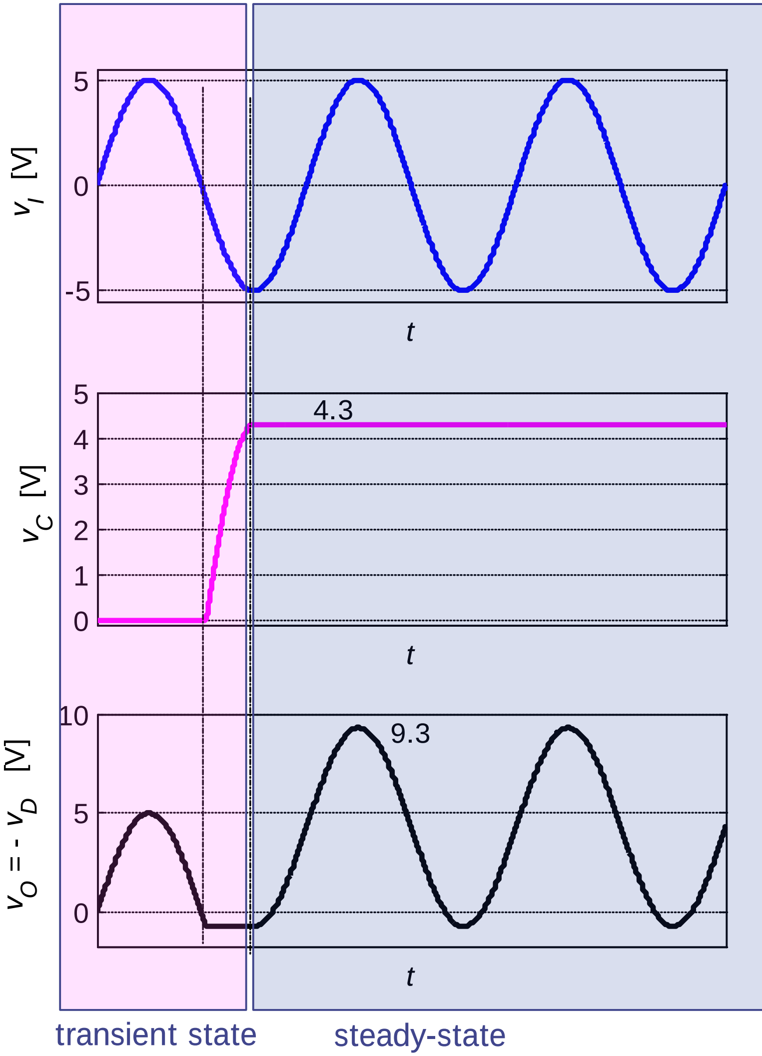



$v_D(t) = -v_I(t) - v_C(t)$

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

Application:

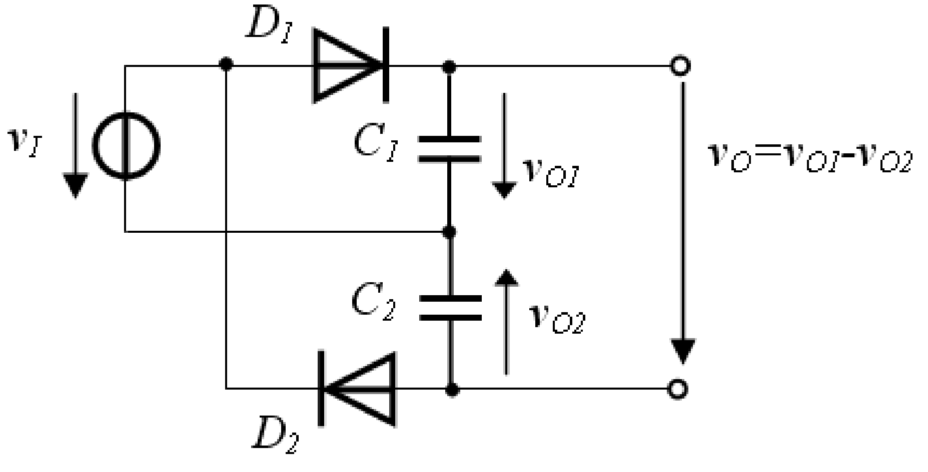
Translation towards positive values (upward)



# 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



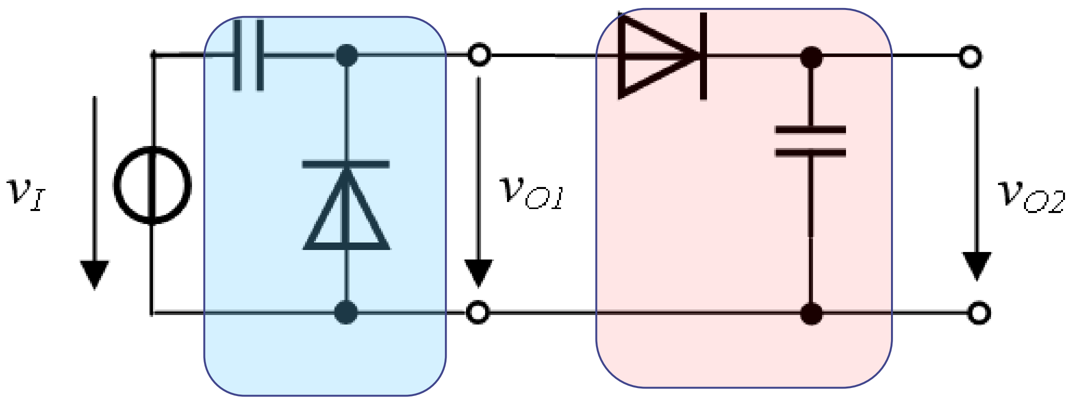

$$v_{O1}(t) = \hat{V}_I$$

$$v_{O2}(t) = -\hat{V}_I$$

$$v_O(t) = \hat{V}_I - (-\hat{V}_I) = 2\hat{V}_I$$

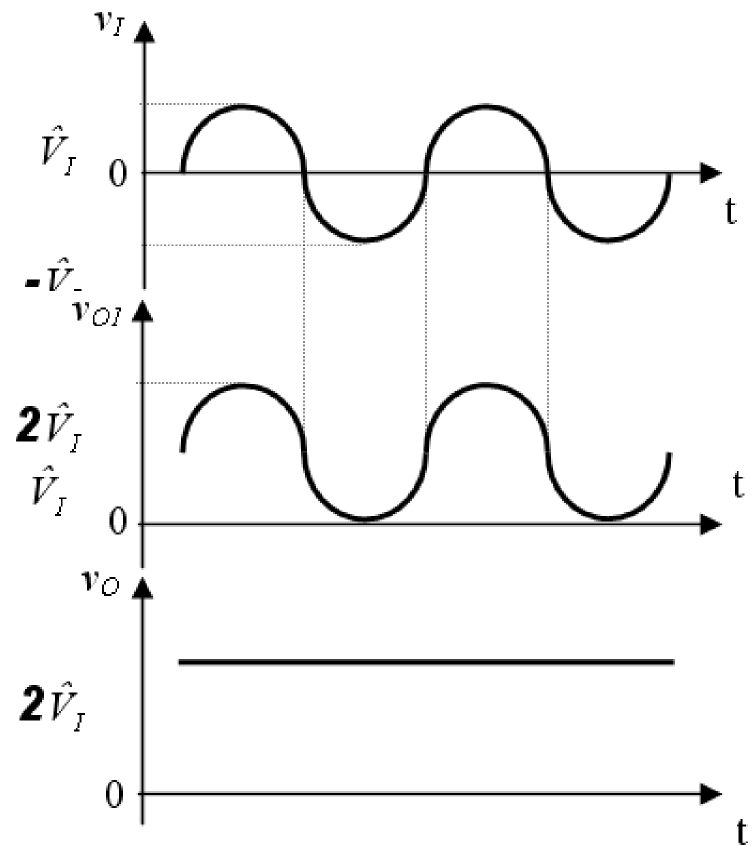
# Voltage doubler

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




Translation toward positive values

Positive peak detector

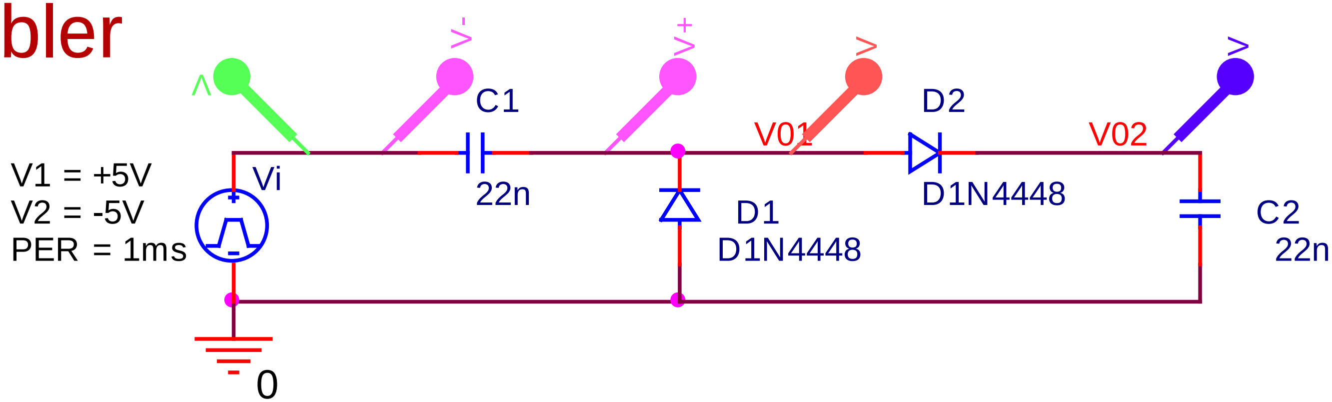


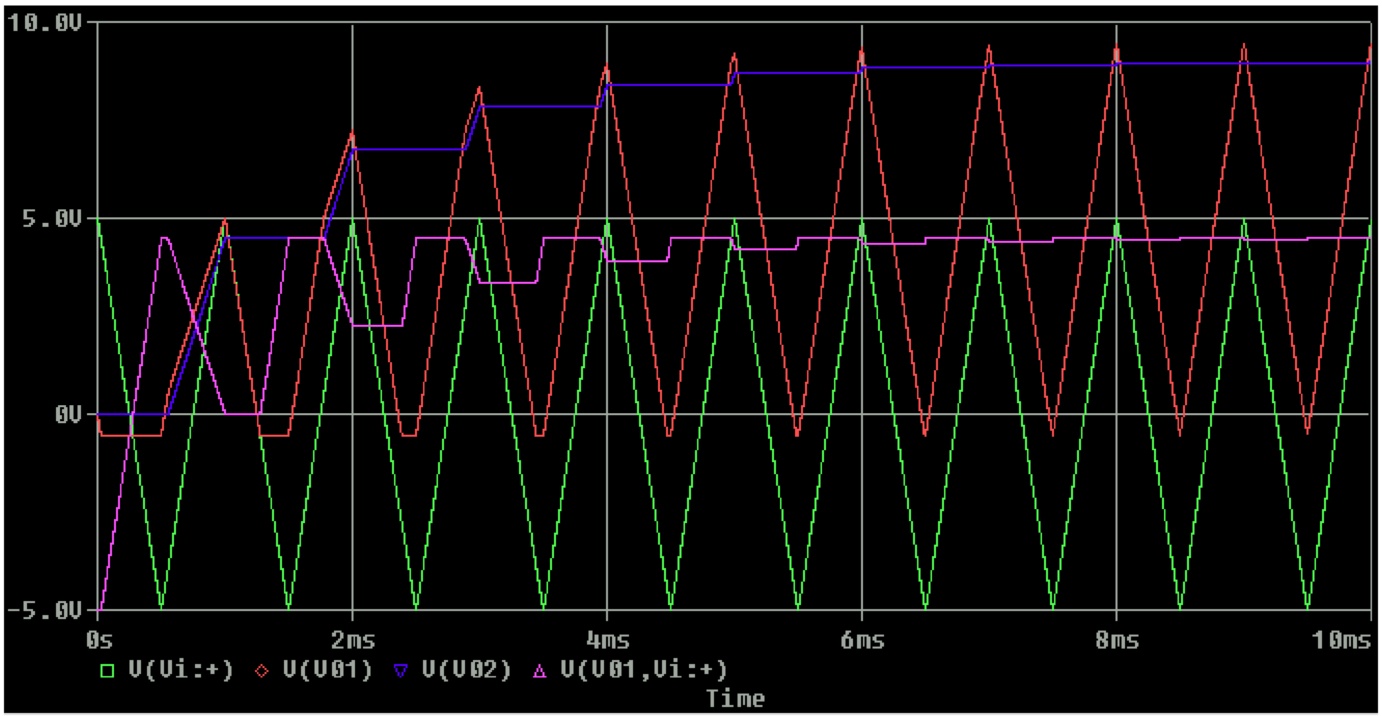

steady-state regime waveforms

$$v_O \approx 2\hat{V}_I$$ neglecting 0.7 V

$$v_O = 2\hat{V}_I - 1.4V$$

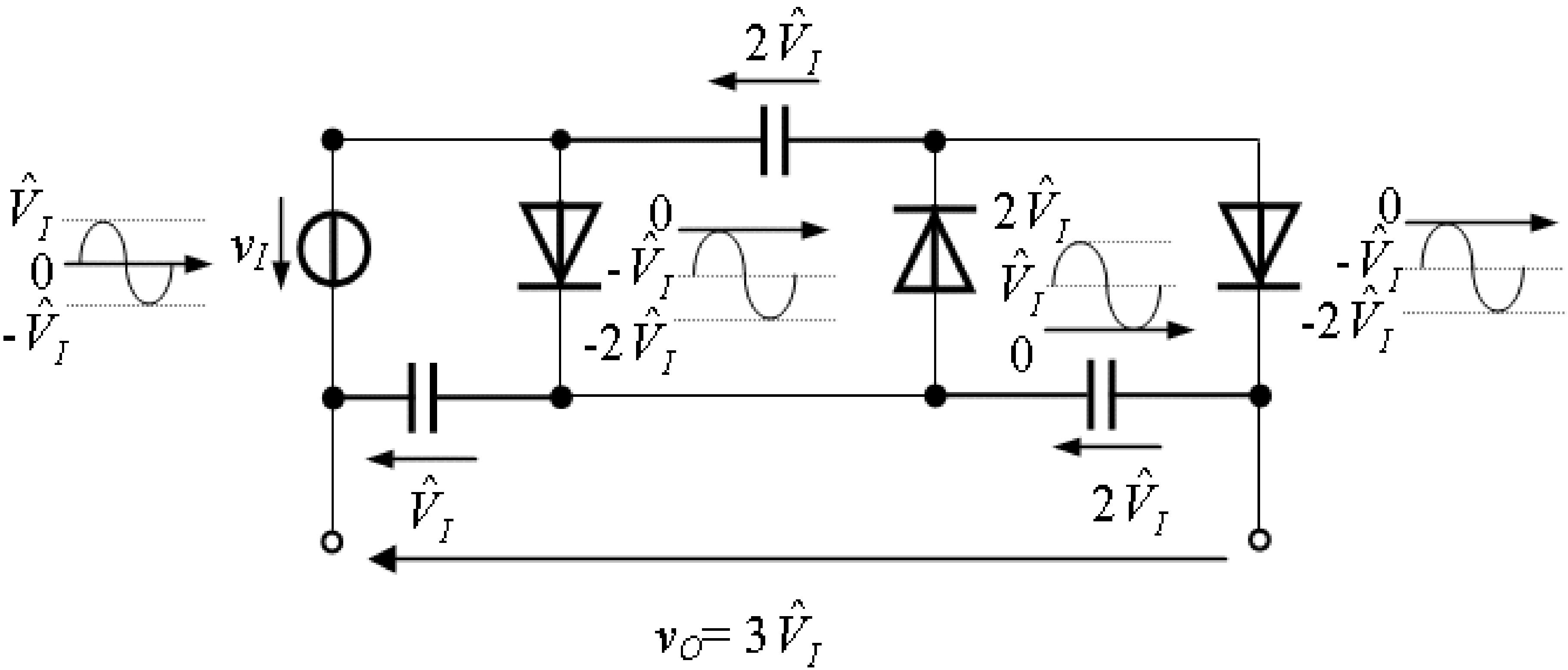
- Voltage doubler



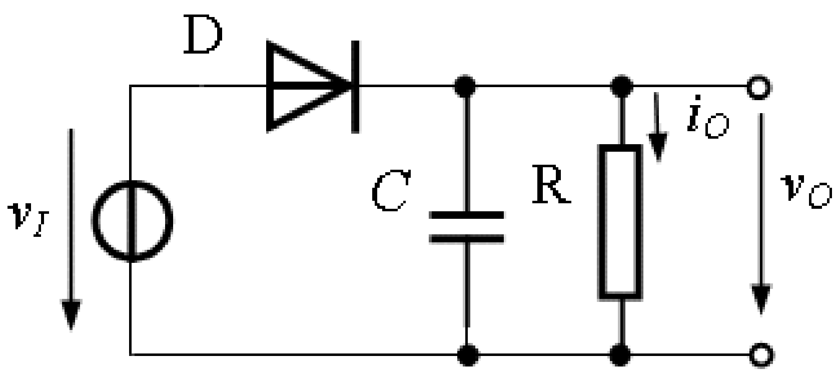
*OPTIONAL*

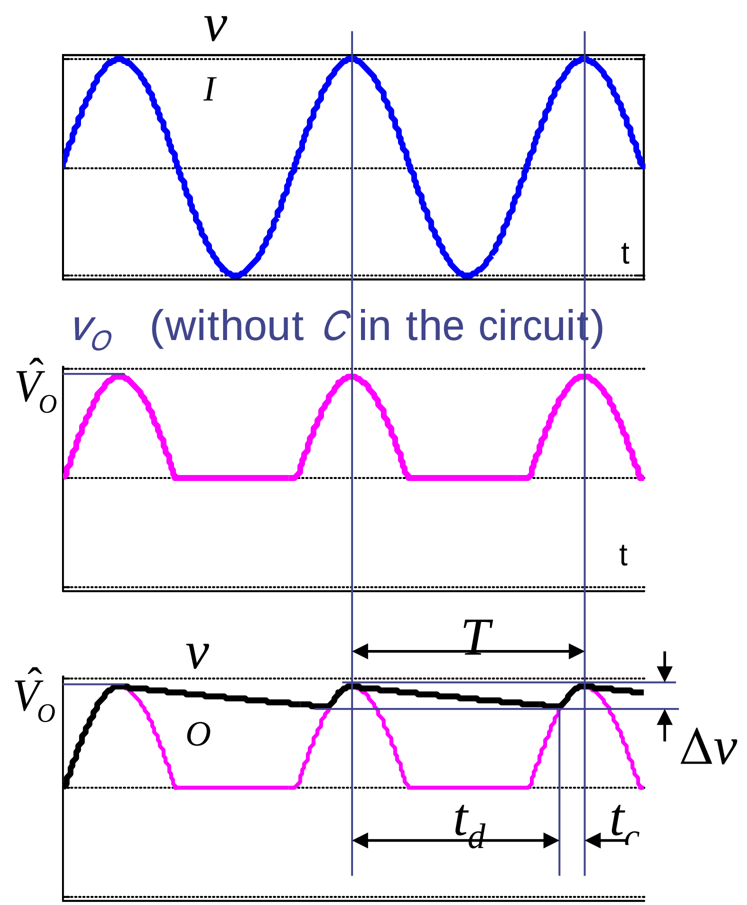
- Voltage tripler



# ➢ Half-wave rectifier w/ capacitive filter (loaded positive peak detector)

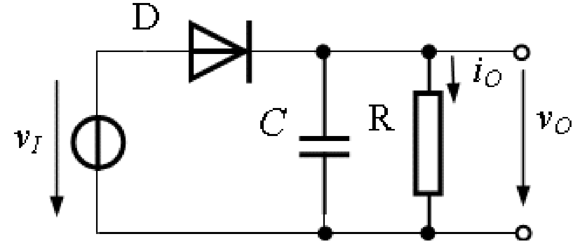
- $v_I$ is the voltage in a secondary winding of a step-down line transformer.
- It is required to obtain an almost dc voltage (on a load resistor)



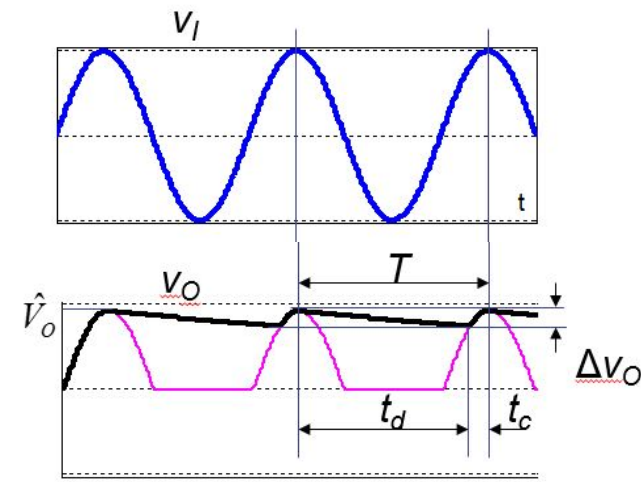

How can the voltage ripple $\Delta v$ be computed?

# ➢ Half-wave rectifier w/ capacitive filter (loaded positive peak detector)




Between two successive voltage peaks, *D* – (off) and *C* discharges through *R*

$$v_c(t) = (1 - e^{-\frac{t}{RC}})V_\infty + V(0)e^{-\frac{t}{RC}}$$




If *RC >>T => * the capacitor discharge during $t_d$ can be approximated with a linear variation of the output voltage (across the capacitor)

$$C\Delta v = I\Delta t$$

$$\Delta t = t_d = T - t_c \approx T$$

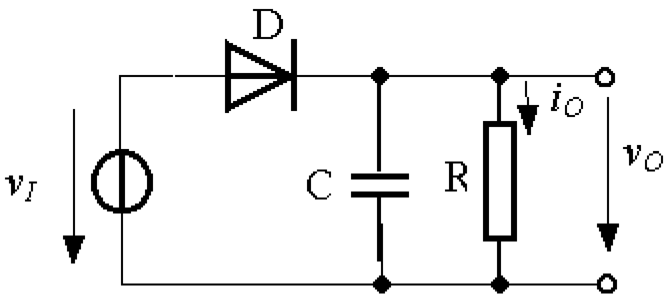
The discharging current is assumed to be constant

$$I = \frac{\hat{V}_O}{R}$$

$$\Delta v = \frac{T}{C} I = \hat{V}_O \frac{T}{RC} = \frac{1}{f} \frac{\hat{V}_O}{RC}$$

# Example

$\hat{V}_I = 10.7\text{V}$ $f$=50Hz $R_L = 100\Omega$ $\Delta v < 1.5\text{V}$ $C$ = ?




$$\hat{V}_O = \hat{V}_I - 0.7\text{V} = 10\text{V}$$

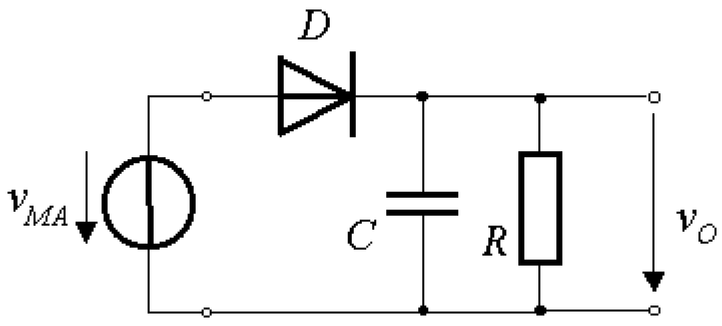
$$\Delta v = \frac{\hat{V}_O}{fRC} < 1.5\text{V}$$

$$C > \frac{\hat{V}_O}{1.5\text{V}fR} = \frac{10}{1.5 \cdot 50 \cdot 100} = 1333\mu\text{F} \qquad C > 1333\mu\text{F}$$

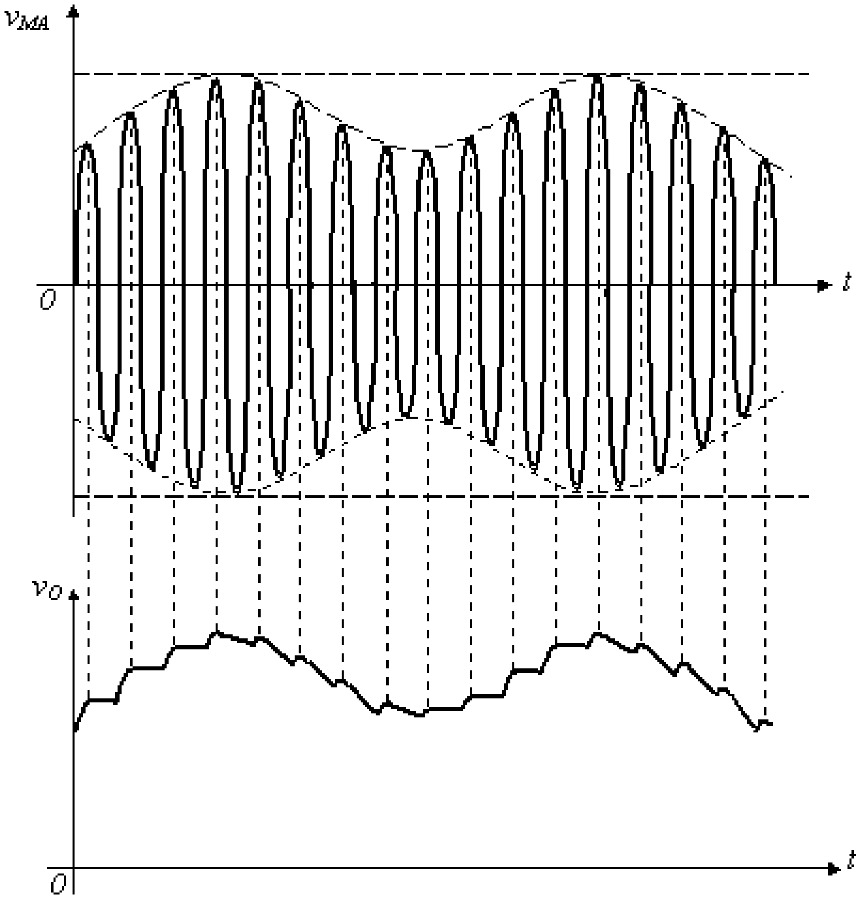
Solution: electrolytic capacitor, $C$ =1500 µF/25 V

- What is the actual value of the output ripple?
- What should be a new value of $C$, in order to reduce the output ripple to half of the initial value?
- Solve again, assuming full-wave rectification.

# AM demodulator

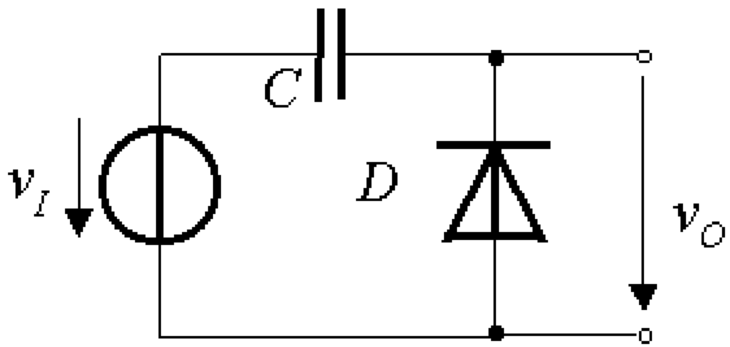


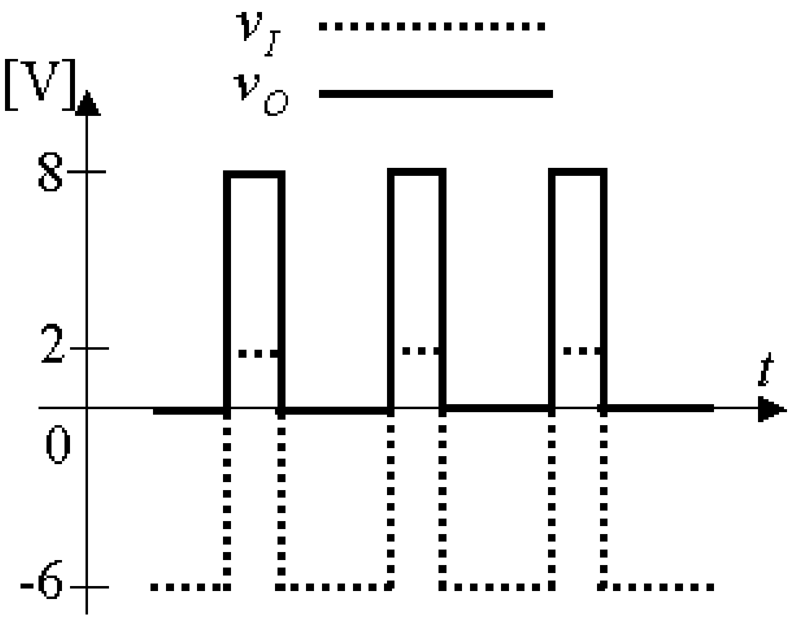

Envelope detector



*OPTIONAL*

# DC component restoration



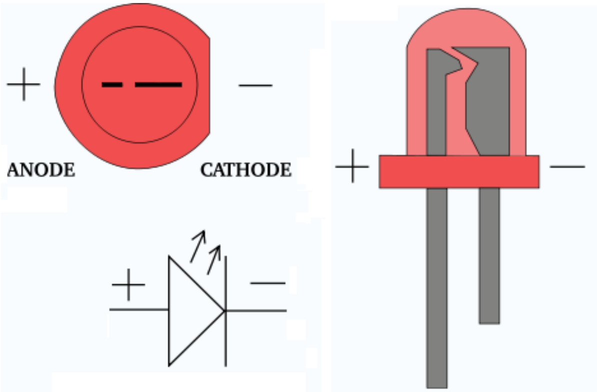



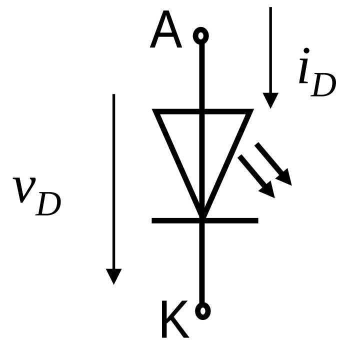

Consider a rectangular wave, transmitted on a line w/ capacitive coupling.

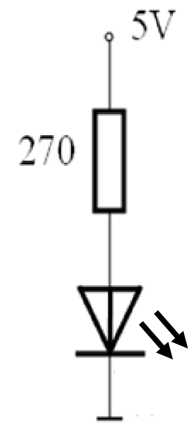
The signal loses its initial dc level.

The upward translation circuit provides a well determined dc component: *dc restoration.*

## ➢ LED – light emitting diode




$I_D$ = ?

- behavior similar to conventional diodes
- 1.5 V to 3 V forward voltage drop
- in forward bias the LED lights up:
  - red, yellow, green, blue, white
  - IR – remote control
- emits radiation in the visible, infrared, or laser range
- typically 5 mA to 20 mA
- *power LED:* 3.5V @ 500 mA

# LEDs and photodiodes

## ➢ LED – excerpt from datasheet

VISHAY.

**TLHR440., TLHO440., TLHY440., TLHG440., TLHP440.**

www.vishay.com

Vishay Semiconductors

**High Efficiency LED in Ø 3 mm Tinted**

**APPLICATIONS**

- Status lights
- Off/on indicator
- Background illumination
- Readout lights
- Maintenance lights
- Legend light

**PRODUCT GROUP AND PACKAGE DATA**

- Product group: LED
- Package: 3 mm
- Product series: standard
- Angle of half intensity: ± 30°

**PARTS TABLE**

| PART | COLOR | LUMINOUS INTENSITY (mcd) | | | at $I_F$ (mA) | WAVELENGTH (nm) | | | at $I_F$ (mA) | FORWARD VOLTAGE (V) | | | at $I_F$ (mA) | TECHNOLOGY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN. | TYP. | MAX. | | MIN. | TYP. | MAX. | | MIN. | TYP. | MAX. | | |
| TLHR4400 | Red | 1.6 | 13 | - | 10 | 612 | - | 625 | 10 | - | 2 | 3 | 20 | GaAsP on GaP |
| TLHO4400-MS12Z | Soft orange | 1.6 | 13 | - | 10 | 598 | - | 611 | 10 | - | 2.4 | 3 | 20 | GaAsP on GaP |
| TLHY4400 | Yellow | 1.6 | 10 | - | 10 | 581 | - | 594 | 10 | - | 2.4 | 3 | 20 | GaAsP on GaP |
| TLHG4405 | Green | 6.3 | 15 | | 10 | 562 | - | 575 | 10 | - | 2.4 | 3 | 20 | GaP on GaP |
| TLHP4401 | Pure green | 1 | 4 | - | 10 | 555 | - | 565 | 10 | - | 2.4 | 3 | 20 | GaP on GaP |

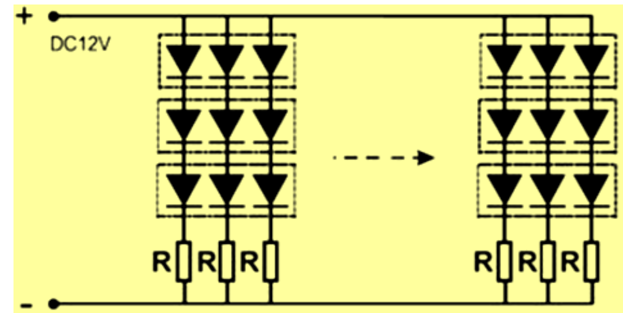
**ABSOLUTE MAXIMUM RATINGS** ($T_{amb}$ = 25 °C, unless otherwise specified)
**TLHR440., TLHO440., TLHY440., TLHG440., TLHP440.**

| PARAMETER | TEST CONDITION | SYMBOL | VALUE | UNIT |
|---|---|---|---|---|
| Reverse voltage | | $V_R$ | 6 | V |
| DC forward current | | $I_F$ | 30 | mA |
| Surge forward current | $t_p \leq 10$ µs | $I_{FSM}$ | 1 | A |
| Power dissipation | $T_{amb} \leq 60$ °C | $P_V$ | 100 | mW |

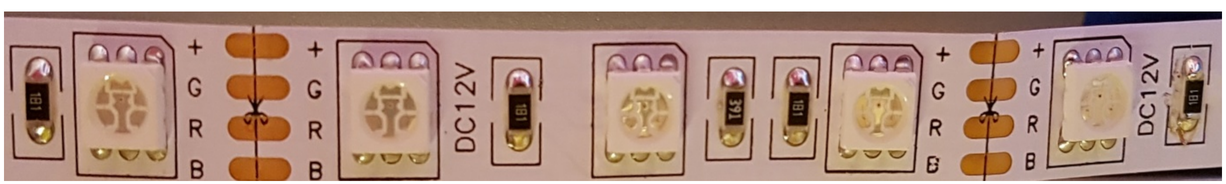
# LEDs and photodiodes

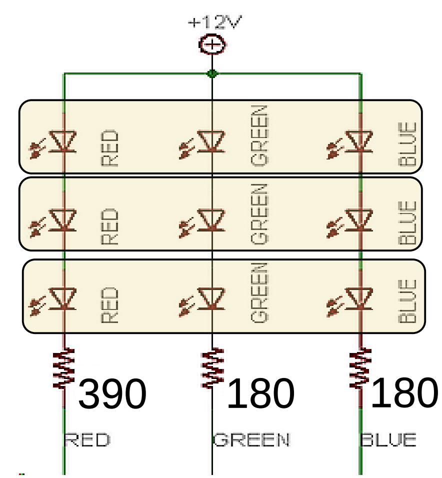
## ➢ LED strips

Single Color LED Strip

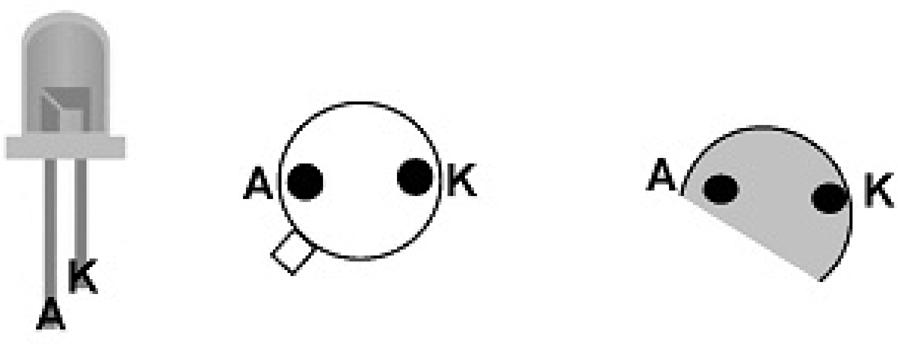



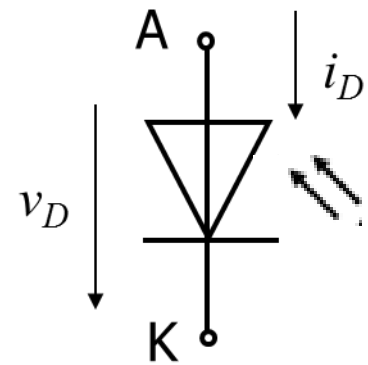

RGB LED Strip



# Photodiodes




- photosensitive pn-junction
- transforms light into electrical signal (current)
- used in reverse bias

# Photodiodes - excerpt from datasheet

EVERLIGHT

**EVERLIGHT ELECTRONICS CO., LTD.**

DEVICE NUMBER : DPD-033-071 REV : 1.0
ECN : PAGE : 1/7

**5mm Silicon PIN Photodiode,T-1 3/4**

MODEL NO : PD333-3C/H0/L2

**Features :**
- Fast response time
- High photo sensitivity
- Small junction capacitance

## Description :

PD333-3C/H0/L1 is a high speed and high sensitive PIN photodiode in a standard 5 $\phi$ plastic package. The device is spectrally matched to infrared emitting diode.

## Applications :

- High speed photo detector
- Camera
- Infrared remote controller for TVs VCR, audio equipment, air conditioner, etc.

**Absolute Maximum Ratings at Ta = 25℃**

| Parameter | Symbol | Rating | Unit | Notice |
|---|---|---|---|---|
| **Reverse Voltage** | $V_R$ | 32 | V | |
| **Power Dissipation** | Pd | 150 | mW | |
| **Lead Soldering Temperature** | Tsol | 260 | ℃ | 4mm from mold body less than 5 seconds |
| **Operating Temperature** | Topr | -25 ~ +85 | ℃ | |
| **Storage Temperature** | Tstg | -40 ~ +85 | ℃ | |

# Summary

Only now we can safely say diodes are not a secret anymore, after studying:

- Full-wave DR rectifiers
- Two-port DC networks
- DRC rectifiers (power supply filtering)
- LEDs and photodiodes

Next week: Zener diodes. Operational amplifiers. Simple comparators with OpAmp.

**To do: Homework 2**