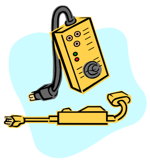
SWITCHING DC TWO-PORT NETWORKS

I. OBJECTIVES

a) To understand the link between the structure and the functions of two-port DC networks.
b) To understand the way to build up the voltage multipliers (double and triple) using simple two-port DC networks.



II. COMPONENTS AND INSTRUMENTATION

You will use a breadboard, three semiconducting diodes of 1N4184 type (the stripe indicates the cathode) and three 100nF capacitors. Because you will apply and measure both dc and ac voltages you will need a dc regulated voltage supply, a signal generator, a digital multimeter and a dual channel oscilloscope.

III. THEORETICAL ASPECTS

The DC two-port networks are switching circuits which containing diodes and capacitors. They have the same circuit configurations as the RD two-port networks, but instead of R they have C.

1. TEMPORAL EXTREME (MAXIMUM/MINIMUM) DC TWO-PORT NETWORKS

We will consider the DC two-port network in Fig.1.

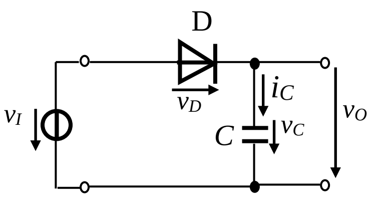


Fig. 1. Positive peak detector.

To analyze this circuit let the input signal be a triangular waveform and let the capacitor be initially discharged. We want to find out the output voltage $v_O(t)$, which is the same with the one across the capacitor $v_O(t) = v_C(t)$, and the voltage across the diode $v_D(t)$. To start with, let us also assume the diode to be ideal.

The potentials at both terminals of the diode can be changed in time. As long as v_D tends to a positive value, the diode conducts, v_D=0V, the capacitor charges up to the instantaneous value of the input voltage and $v_C(t)$ increases. A current i_C>0 flows through the circuit, whose value is determined only by the value of the capacitor and the rate of increase of the input voltage:

$$i_C = C\frac{dv_I}{dt}$$

Due to the ideal diode, the output voltage will be equal to the input voltage.

As long as v_D<0V, the diode is cutoff, so there is no current through the circuit, which makes the voltage across the capacitor to remain unmodified: $v_C(t)=constant$.

According to KVL we have:

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

The waveforms of the output voltage and of the voltage across the capacitor can be visualized in Fig. 2.

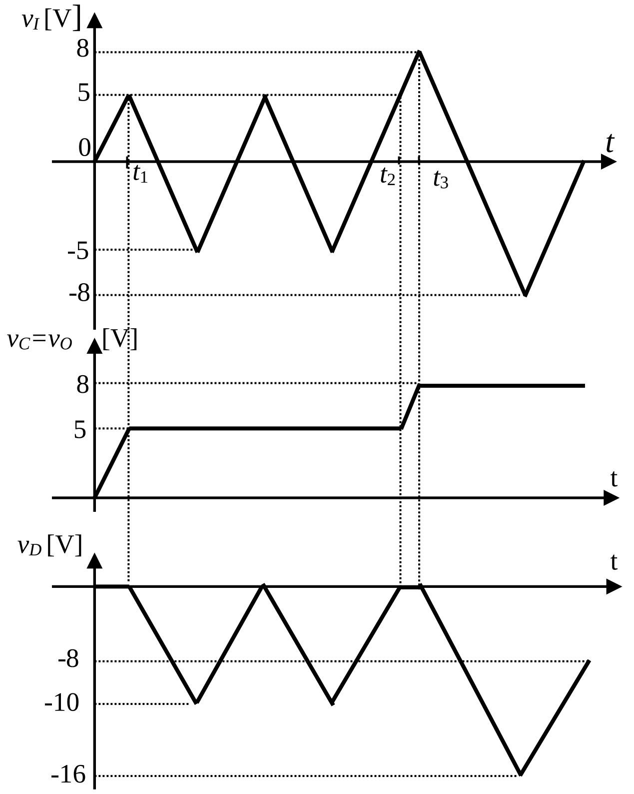


Fig. 2. Waveforms for the positive peak detector

We can notice that at each moment of time the value of the output voltage v_O is equal to the greatest positive value taken by the input voltage at every previous time moment. For this reason the circuit is called a ***maximum two-port*** **or** ***positive peak detector***.

If we consider a voltage drop of 0.7V across the conducting diode, for $t \in [t_1, t_2]$; v_O=4.3V and for $t>t_3$, v_O=7.3V.

To obtain a ***minimum two-port network*** we can use a circuit similar to the one for the maximum, but reversing the orientation of the diode.

2. TRANSLATION DC TWO-PORT NETWORKS

For the circuit in Fig. 1, if we consider the output across the diode, we can re-draw the circuit as in Fig. 3.

The voltage waveforms remain as in Fig. 2, only that the output voltage will be considered across the diode, $v_O(t)=v_D(t)$.

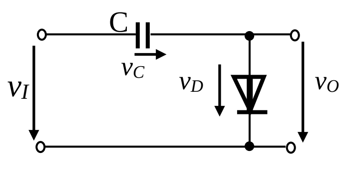


Fig. 3. Downward translation circuit

As the relationship $v_O(t)=v_I(t)-v_C(t)$ shows us, at every moment of time the output voltage results by translating downward the voltage v_I, with the voltage across the capacitor. Because $v_C(t) \geq 0$,

v_I is always translated towards negative values, and that is why the circuit is called a ***downward translation* DC two-port network**. Please note that the in this circuit the voltage across the capacitor is always positive and the output voltage is always smaller than or equal to zero.

The circuit shown in Fig.4 is an ***upward translation DC two-port network*:**

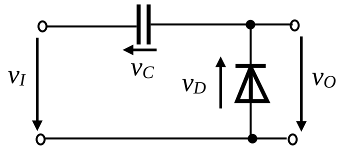


Fig.4. Upward translation circuit.

Its corresponding waveforms are plotted in Fig.5 with a full line for the ideal diode and with a broken line for diodes with 0.7V voltage drop across for conducting diodes. The output voltage v_O is given by the equation:

$$v_O(t) = v_I(t) + v_C(t)$$

Because $v_C \geq 0$; v_I is translated upwards, at every moment, with a value equal to the voltage across the capacitor v_C, that is the absolute value of the negative input voltage peek until that moment.

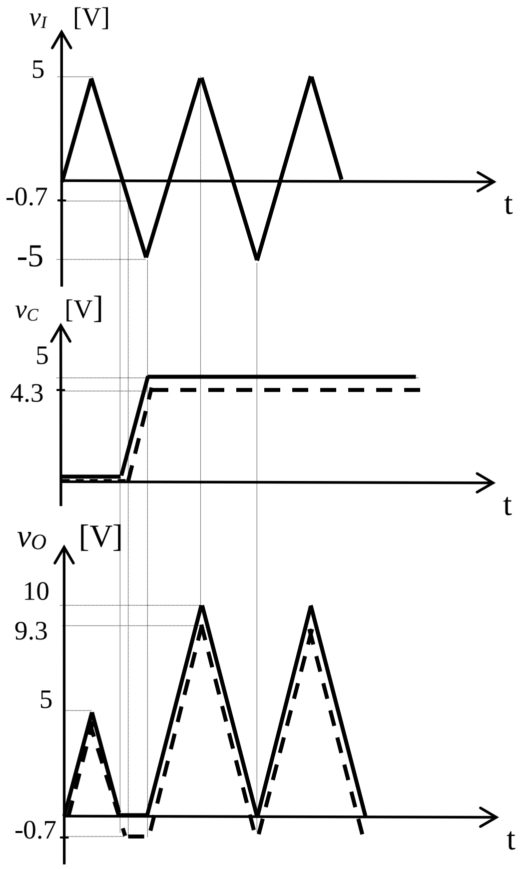


Fig. 5. Waveforms of the upward translation two-port network in two cases:
D ideal;
0.7 V across *D* în conduction

3. VOLTAGE DOUBLER

Think of it as a cascading connection between an upward translation two-port network (from v_I to v_{O1}) and a positive peak detector (from v_{O1} *to* v_O).

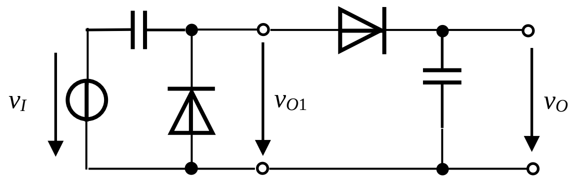


Fig. 6. Voltage doubler using a translation and a peak detector.

The waveforms in steady-state regime, in the case of a sinusoidal input signal with $\hat{V}_I$ amplitude are plotted in Fig.7.

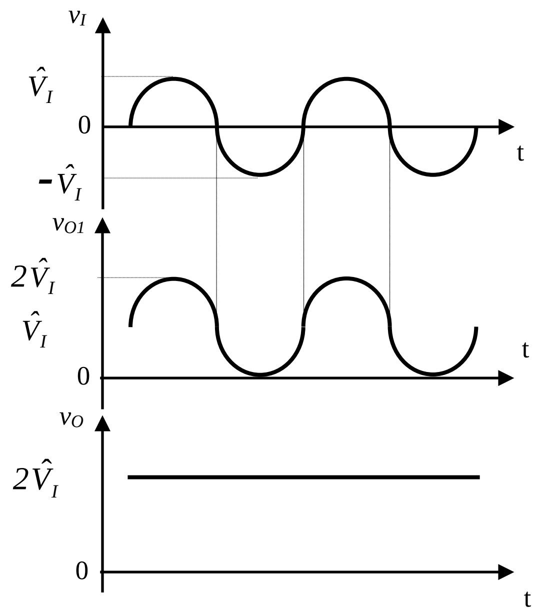


Fig.7. Waveforms in the steady-state regime for the doubler in Fig. 6

IV. PREPARATION

The exercises in this paragraph will be solved using the constant voltage drop diode model.

1.P. TEMPORAL EXTREME (MAXIMUM/MINIMUM) DC TWO-PORT NETWORKS

WAVEFORMS AND OPERATION OF THE CIRCUIT

- How do the waveforms for $v_O(t)$ and $v_D(t)$ look like, in steady state, for the circuits shown in Fig. 8 and Fig. 9 if $v_I(t)$=5V d.c. (Fig.8) and $v_I(t)$= -5V d.c. (Fig.9)?
- How do the waveforms for $v_O(t)$ and $v_D(t)$ look like, in steady state, for the circuits shown in Fig. 8 and Fig. 9 if $v_I(t)$ is a sinusoidal voltage with 0.3V amplitudes?
- How do the waveforms for $v_O(t)$ and $v_D(t)$ look like, in steady state, for the circuits shown in Fig. 8 and Fig. 9 if $v_I(t)$ is a sinusoidal voltage with 10V amplitudes?

2.P. TRANSLATION TWO-PORT DC NETWORK (UPWARD/DOWNWARD)

WAVEFORMS AND OPERATION OF THE CIRCUIT

- How do the waveforms for $v_O(t)$ and $v_C(t)$ look like, in steady state, for the circuits shown in Fig. 10 and Fig. 11 if $v_I(t)$ is a sinusoidal voltage with 0.3V amplitudes?
- How do the waveforms for $v_O(t)$ and $v_C(t)$ look like, in steady state, for the circuits shown in Fig. 10 and Fig. 11 if $v_I(t)$ is a sinusoidal voltage with 10V amplitudes?

3.P. VOLTAGE DOUBLER

WAVEFORMS AND OPERATION OF THE CIRCUIT

• How do the waveforms for $v_{O1}(t)$ and $v_{C1}(t)$ look like, in steady state, for the circuit shown in Fig. 12 if $v_I(t)$ is a sinusoidal voltage with 10V amplitude?

• How do the waveforms for $v_O(t)$ and $v_{D2}(t)$ look like, in steady state, for the circuit shown in Fig. 12 for the above conditions?

• How can you build the circuit shown in Fig. 12 using the circuits shown in Fig. 8 and Fig. 10?

Optional

4.P. VOLTAGE TRIPLER

THE OPERATION OF THE CIRCUIT

• What is the function of D1C1 group from the circuit shown in Fig. 13 considering v_I as input voltage and v_1 as output voltage?

• What is the function of D2C2 group from the circuit shown in Fig. 13 considering v_1 as input voltage and v_2 as output voltage?

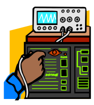
• What is the function of D3C3 group from the circuit shown in Fig. 13 considering v_2 as input voltage and v_3 as output voltage?

• What is the value of v_O for the circuit shown in Fig. 13 if the amplitude of the sinusoidal input voltage is 10V?

V. EXPLORATIONS AND RESULTS

1. TEMPORAL EXTREME (MAXIMUM/MINIMUM) DC TWO-PORT NETWORKS

1.1 TEMPORAL MAXIMUM TWO-PORT NETWORK - WAVEFORMS AND THE OPERATION OF THE CIRCUIT



Exploration

Build the circuit shown in Fig. 8.

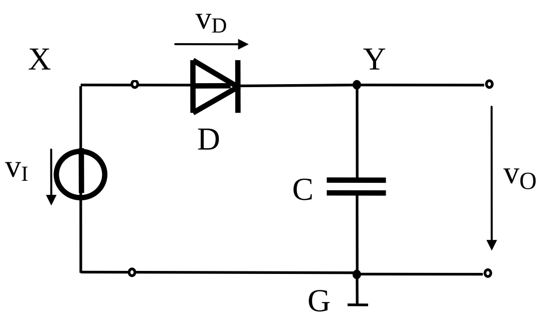


Fig. 8. Temporal maximum two-port

• You will apply at the input a 5V d.c. voltage from dc regulated voltage supply.

• V_D and V_O are measured using a digital multimeter.

• At the input of the circuit apply a sinusoidal voltage with 500 Hz frequency of and 0.3V amplitude obtained from the signal generator.

• The signals v_I and v_O are displayed on the oscilloscope set in Y-t mode, both of the channels being directly coupled and having 0V in the centre of the screen. The two leads are connected in the points X, Y and the ground in the point G.
• The measurements are done again for 10V amplitude of v_I.

Results

• The values of v_O and v_D for v_I =5V d.c.
• The waveforms for $v_I(t)$, $v_O(t)$ and $v_D(t)$ considering 0.3V and 10V amplitude for the sinusoidal input voltage; $v_D(t)$ is obtained from the difference between $v_I(t)$ and $v_O(t)$.

1.2 TEMPORAL MINIMUM TWO-PORT NETWORK - WAVEFORMS AND THE OPERATION OF THE CIRCUIT

Exploration

Build the circuit shown in Fig. 9.
• You will apply at the input a - 5V d.c. voltage from dc regulated voltage supply.
• V_D and V_O are measured using a digital multimeter.
• At the input of the circuit apply a sinusoidal voltage with 500 Hz frequency of and 0.3V amplitude obtained from the signal generator.
• The signals v_I and v_O are displayed on the oscilloscope set in Y-t mode, both of the channels being directly coupled and having 0V in the centre of the screen. The two leads are connected in the points X, Y and the ground in the point G.
• The measurements are done again for 10V amplitude of v_I.

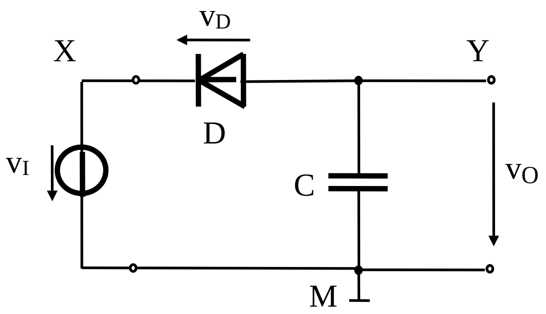


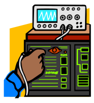
Fig. 9. Temporal minimum two-port

Results

• The values of v_O and v_D for v_I = -5V d.c.
• The waveforms for $v_I(t)$, $v_O(t)$ and $v_D(t)$ considering 0.3V and 10V amplitude for the sinusoidal input voltage; $v_D(t)$ is obtained from the difference between $v_I(t)$ and $v_O(t)$.

2. TRANSLATION TWO-PORT DC NETWORK (UPWARD/DOWNWARD)

2.1 UPWARD TRANSLATION DC TWO-PORT NETWORK – WAVEFORMS AND THE OPERATION OF THE CIRCUIT



Exploration

Build the circuit shown in Fig. 10.

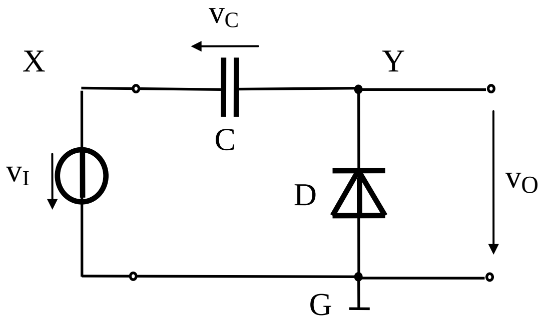


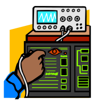
Fig. 10. Upward translation two-port

• At the input of the circuit it is applied a sinusoidal voltage with frequency of 500 Hz and amplitude of 0.3V obtained from the signal generator.
• The signals v_I and v_O are visualized on the calibrated oscilloscope set in Y-t mode, both of the channels being directly coupled and having 0V in the centre of the screen. The two leads are connected in the points X, Y and the ground in the point G.
• The measurements are done again for 10V amplitude of v_I.

Results

• The waveforms for $v_I(t)$, $v_O(t)$ and $v_D(t)$ considering the following values for the amplitude of the sinusoidal input voltage: 0.3V and 10V. $v_C(t)$ is computed as the difference between $v_I(t)$ and $v_O(t)$.

2.2 DOWNWARD TRANSLATION DC TWO-PORT NETWORK – WAVEFORMS AND THE OPERATION OF THE CIRCUIT



Exploration

Build the circuit shown in Fig. 11.

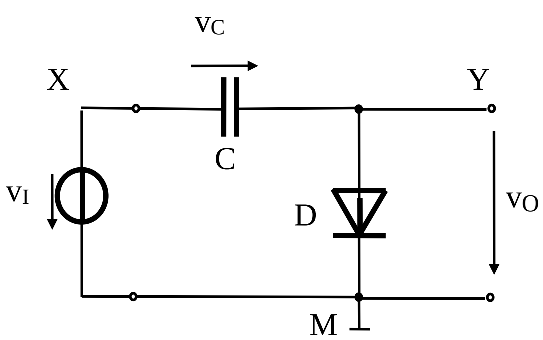


Fig. 11. Downward translation two-port

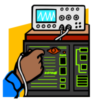
• At the input of the circuit it is applied a sinusoidal voltage with frequency of 500 Hz and amplitude of 0.3V obtained from the signal generator.
• The signals v_I and v_O are visualized on the calibrated oscilloscope set in Y-t mode, both of the channels being directly coupled and having 0V in the centre of the screen. The two leads are connected in the points X, Y and the ground in the point G.
• The measurements are done again for 10V amplitude of v_I.

Results

• The waveforms for $v_I(t)$, $v_O(t)$ and $v_D(t)$ considering the following values for the amplitude of the sinusoidal input voltage: 0.3V and 10V. $v_C(t)$ is computed as the difference between $v_I(t)$ and $v_O(t)$.

3. VOLTAGE DOUBLER

3.1 WAVEFORMS AND THE OPERATION OF THE CIRCUIT



Exploration

Build the circuit shown in Fig. 12.
• At the input of the circuit a sinusoidal voltage is applied with 500Hz frequency and 10V amplitude obtained from the signal generator.
• $v_I(t)$, $v_{O1}(t)$ and $v_O(t)$ are visualized on the oscilloscope. Because you can visualize only two signals simultaneously you will visualize first $v_I(t)$ and $v_{O1}(t)$ and then $v_I(t)$ and $v_O(t)$.
Be careful when setting the oscilloscope (see previous sections).

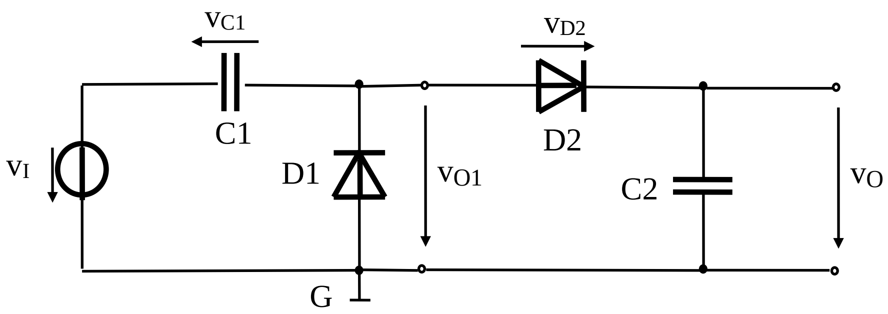


Fig. 12. Voltage doubler

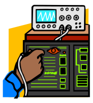
Results

• Draw the waveforms for $v_I(t)$, $v_{O1}(t)$, $v_O(t)$, $v_{C1}(t)$ and $v_{D2}(t)$ for 10V amplitude of the input voltage.

Optional

4. VOLTAGE TRIPLER

4.1 WAVEFORMS and the operation of the circuit



Exploration

Build the circuit shown in Fig. 13.

• At the input of the circuit a sinusoidal voltage is applied with 500Hz frequency and 10V amplitude obtained from the signal generator.

• $v_I(t)$ and $v_O(t)$ are visualized on the oscilloscope.

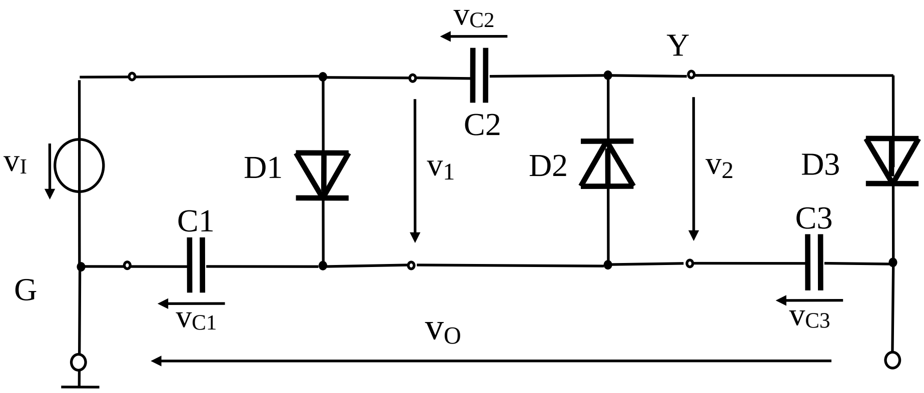


Fig. 13. Voltage tripler

Results

• Draw the waveforms for $v_I(t)$, $v_1(t)$, $v_2(t)$ and $v_O(t)$ for values of 10V of the amplitude of v_I.

REFERENCES

1. Oltean, G., Electronic Devices, Editura U.T. Pres, Cluj-Napoca, ISBN 973-662-220-7, 2006
2. Sedra, A. S., Smith, K. C., Microelectronic Circuits, Fifth Edition, Oxford University Press, ISBN: 0-19-514252-7, 2004
3. http://www.bel.utcluj.ro/dce/didactic/ed/ed.htm