

Half-wave rectification using a tube diode

Objects of the experiments

- Using a tube diode as a half-wave rectifier for a sinusoidal alternating voltage

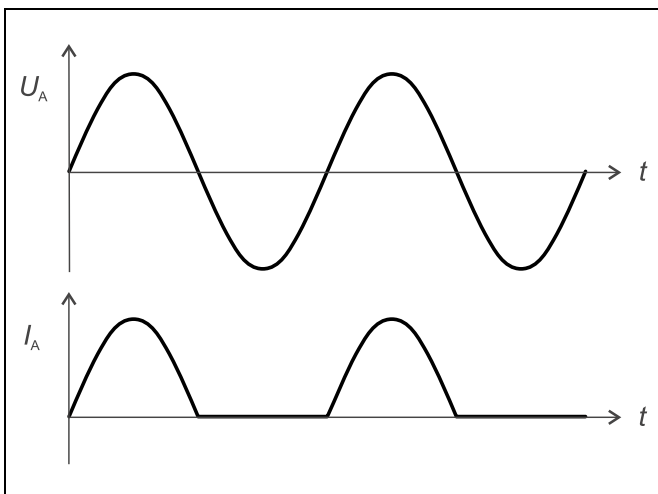


Fig. 1 The anode voltage $U_A(t)$ and the anode current $I_A(t)$ of a tube diode operated as a rectifier.

Principles

A tube diode consists of a hermetically sealed, evacuated glass bulb containing two electrodes: a thermionic cathode that emits electrons and an anode (see Fig. 1). If a suitable voltage is applied between the cathode and the anode, there will be an electric current between the two poles.

The cathode is a filament that is made to glow by an electric voltage. The hot filament emits electrons (thermionic emission). If the anode potential is positive with respect to the cathode potential, the electrons are accelerated towards the anode, where they are absorbed ("anode current"). The magnitude of the anode current depends, among other things, on the voltage between the anode and the cathode ("anode voltage"). If the polarity of the anode voltage is reversed, there can be no current because the electrons escaping from the cathode cannot run against the field directed in the opposite direction.

The relation between the anode current and the anode voltage is described by the characteristic of the diode (see experiment P3.8.1.1). If the polarity of the anode with respect to the cathode is positive, and the anode current increases with increasing anode voltage until it reaches a limit ("saturation current"). At this point the voltage is so high that all electrons escaping from the cathode are absorbed. A further increase of the heating voltage, therefore, has no longer any influence on the anode current. However, an increase of the heating voltage leads to the emission of more electrons by the cathode. In this case, the saturation current is larger.

The diode acts as an electric valve letting a current through only in one direction. One of the simplest and most important applications of the diode, therefore, is the conversion of an alternating current into a direct current. For this a sinusoidal alternating voltage between the anode and the cathode is applied. While the anode potential with respect to the cathode is positive, there is an anode current, which can be seen, for example, as a voltage drop at a resistor series-connected to the diode. During each "negative" half-wave of the alternating voltage the diode blocks the current (see Fig. 1). This is called the rectification of an alternating voltage.

Apparatus

1 planar diode P	555 210
1 universal stand P	555 200
1 measuring resistor 100 Ω , 4 W	536 131
1 DC power supply 0 ... 500 V	521 65
or	
1 DC power supply 0 ... 20 V	521 54
1 variable low voltage transformer 0 ... 250 V	521 40
1 two-channel oscilloscope 303	575 211
1 probe, 100 MHz, 1:1 or 10:1	575 231
1 screened cable BNC/4 mm	575 24
1 safety connection lead, 50 cm, blue	500 622
2 safety connection leads, 1 cm, red	500 641
3 safety connection leads, 1 cm, blue	500 642

Setup

The experimental setup is illustrated in Fig. 2. Fig. 3 shows the corresponding connection diagram.

Setup of the diode P:

- To insert the diode P into the universal stand P, properly position the glass pins and then gently press the tube until all pin contacts are securely seated in their sockets.

Connection of the heating voltage:

If the DC power supply 0 ... 500 V is used:

- Use safety connection leads to connect the negative pole of the heating voltage output to the socket F4 of the universal stand P and the positive pole to the socket F3.
- Set the output voltage to about 6 V.

If the DC power supply 0 ... 20 V is used:

- Use safety connection leads to connect the negative pole to the socket F4 of the universal stand P and the positive pole to the socket F3.
- Set the output voltage to about 6 V.

Safety notes

The tube of the diode P is a thin-walled, evacuated glass bulb. There is danger of implosion! When the tube is in operation, contact-hazardous voltages can be present at the connection field of the universal stand P!

- Do not subject the tube to mechanical stresses.
- Use only safety connection leads at the connection field of the universal stand P.
- Observe the notes contained in the instruction sheet of the diode P (555 210) and of the universal stand P (555 200).

Connection of the alternating voltage:

- Connect the anode connection lead of the diode P to the right safety socket of the variable low voltage transformer with a safety connection lead: plug the anode connection lead into the back of the plug.
- Connect the left safety socket of the variable low voltage transformer to the measuring resistor 100 Ω and the resistor to socket F4 of the universal stand P.

Connection of the oscilloscope:

- Connect the probe 100 MHz to channel I of the oscilloscope, attach the 4-mm adapter, and connect it to the right safety socket of the variable low voltage transformer.
- Connect the screened cable BNC/4 mm to channel II of the oscilloscope, and plug it into the left socket of the measuring resistor 100 Ω . Plug the connector for the screening into the right socket of the resistor.

Note: Channel I of the oscilloscope displays the alternating voltage between the anode and the cathode, while channel II displays the voltage drop at the 100- Ω resistor. The ground connection over the oscilloscope lies between the variable low voltage transformer and the 100- Ω resistor. The signal in channel II is therefore inverted.

Carrying out the experiment

- Check the connections with the help of Fig. 3.
- Switch on the power supply, and set the heating voltage to about 6 V.

The filament should immediately be red-hot.

- If necessary, cautiously turn the tube to check whether the contact between the universal stand P and the diode P is all right.
- Switch on the variable low voltage transformer and choose an output voltage of about 20 V.
- Switch on the oscilloscope, and study the signals with the following settings:

probe:	ratio 10:1
mode:	dual
time base:	for example 10 ms/DIV.
Y-scan, channel I:	for example 2 V/DIV.
Y-scan, channel II:	for example 50 mV/DIV., inverted

- Increase the output voltage of the variable low voltage transformer slowly, observing the oscilloscope signals.
- Increase the heating voltage slowly (max. 7,5 V), observing the oscilloscope signals.

Measuring example

(see Fig. 4)

Evaluation and results

The tube diode blocks the anode current at every other half-wave. When the anode voltage is positive, the anode current increases and follows the anode voltage (Fig. 4 below). If the peak value of the anode voltage is increased, the peak value of the anode current increases too (Fig. 4 middle), but only as long as it does not reach the saturation region of the diode characteristic. Then a plateau appears in the maximum of the anode current (Fig. 4 above).

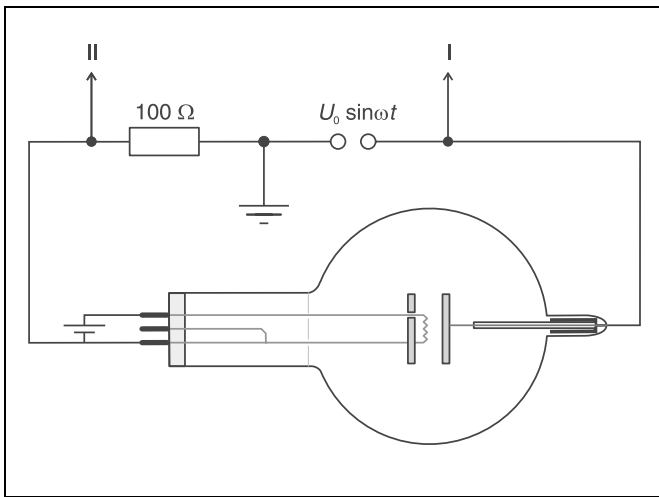
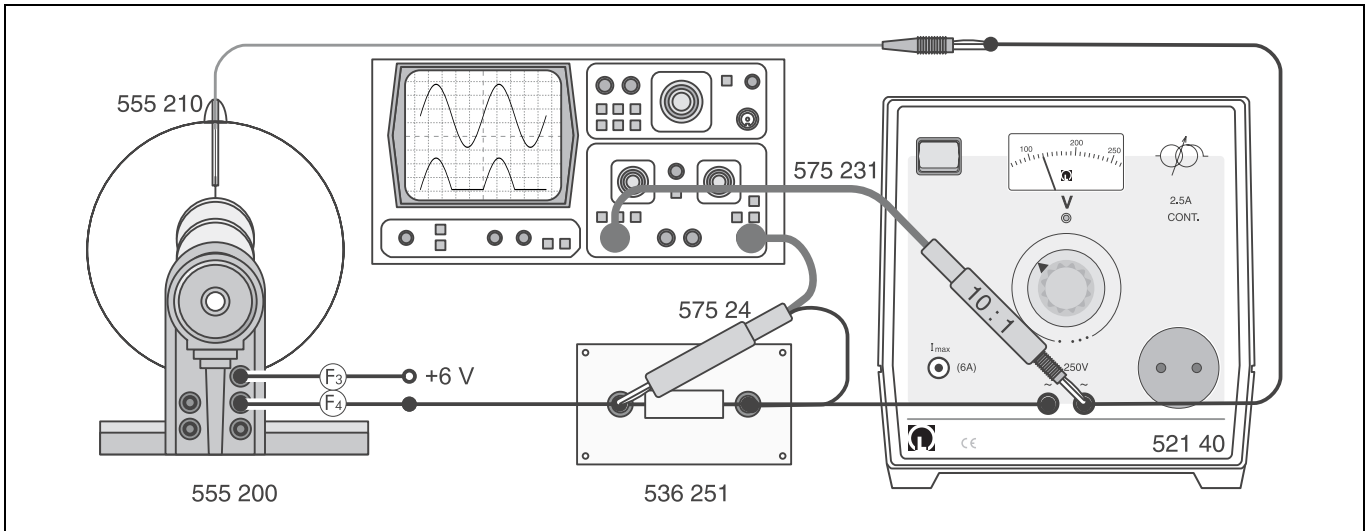


Fig. 2 Experimental setup for the half-wave rectification of an alternating voltage with a tube diode

Fig. 3 Connection diagram for the experimental setup

More electrons are emitted from the cathode through an increase in the heating voltage. This enables the maximum value of the anode current to be changed. The plateau region disappears, and the curve corresponding to the anode current is again sinusoidal.

Supplementary information

It is possible to make use of both half-waves of the sinusoidal alternating voltage. For this complicated circuits are required in which several diodes are used at the same time. We refer the interested reader to more comprehensive literature.

Fig. 4 Time dependence of the anode voltage (above in each panel) and of the voltage at the 100-Ω resistor (below in each panel) for “low”, “medium” and “high” peak value of the anode voltage.

