

## Training Oscilloscope

### STUDY THE PHYSICAL PRINCIPLES OF THE TIME-RESOLVED DISPLAY OF ELECTRICAL SIGNALS USING AN OSCILLOSCOPE.

- Investigating the deflection of an electron beam in an electric field.
- Investigating the deflection of an electron beam in a magnetic field.
- Demonstrating the display of signals on an oscilloscope, using the periodic signal from a function generator.
- Calibrating the frequency control of the sawtooth generator.

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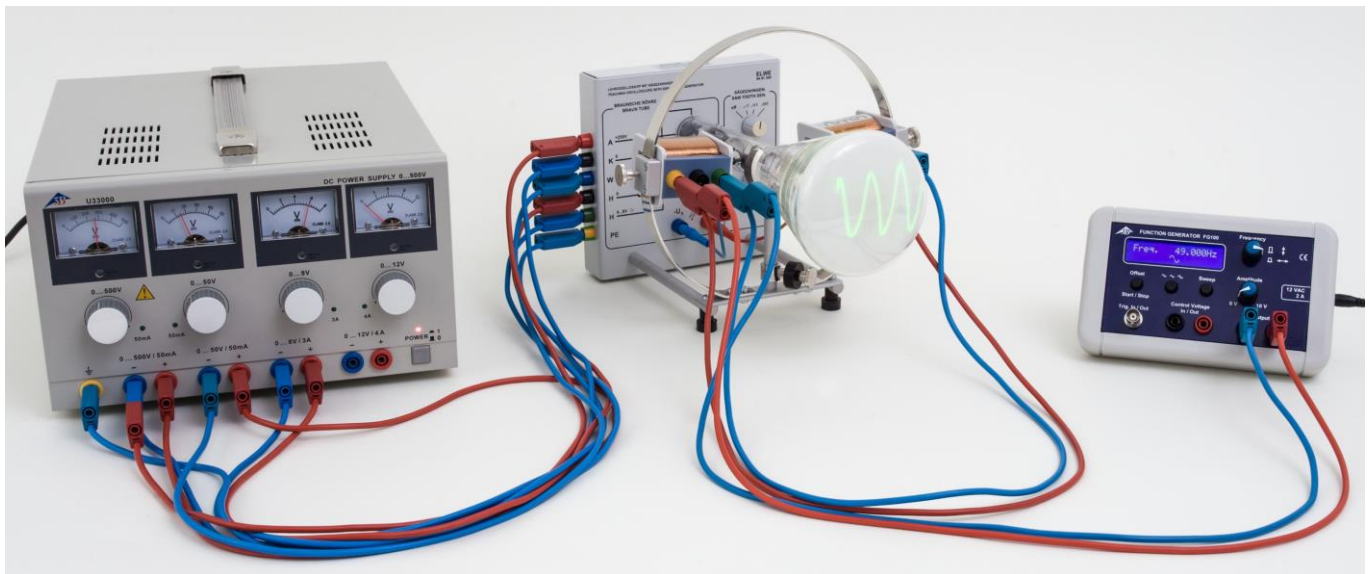


Fig. 1: Measurement set-up.

### BASIC PRINCIPLES

An important application of thermionic emission in a high vacuum is the cathode ray oscilloscope, in which the Braun tube is an essential component. In the form used in the student oscilloscope, the electron-optical system of the Braun tube, which is visible from the outside, consists of a thermionic cathode surrounded by a “Wehnelt cylinder” and a pinhole disc at the anode potential. A proportion of the electrons that are accelerated towards the anode pass through the pinhole disc and form a beam, which is observed on the tube’s fluorescent screen as a green spot of light. Because the tube is filled with neon at a low pressure, the electron beam is concentrated through collisions with gas atoms, and is visible as thin threads emitting reddish light. A negative voltage that is applied to the Wehnelt cylinder also contributes to

the concentrating of the beam. Technical oscilloscopes usually have additional arrangements for post-acceleration (intensification) and focusing of the beam, but for simplicity and clarity these are not present in the student oscilloscope.

Behind the anode, there is a pair of plates with their planes parallel to the electron beam, which can be connected to a sawtooth generator (see fig. 2). The electric field produced by the sawtooth voltage  $U_x(t)$  deflects the beam horizontally, so that it moves across the fluorescent screen from left to right at a constant speed, then flies back to the starting point. This process is repeated cyclically at a frequency that can be adjusted.

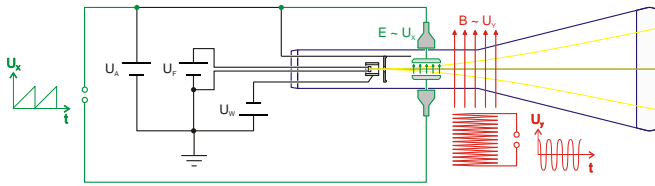


Fig. 2: Schematic diagram of the student oscilloscope, viewed from above.

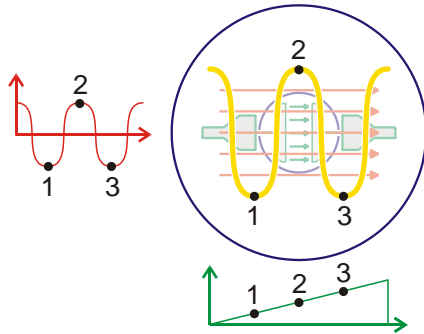


Fig. 3: Time-resolved display of a periodic signal.

During its left-to-right movement, the electron beam can also be deflected vertically by a magnetic field, and for this a voltage  $U_V(t)$  is applied to the coils that are external to the tube. If this voltage is time-dependent, the time-resolved variations are displayed on the screen (see fig. 3). Such time-dependent voltages might be, for example, the periodic output voltage from a function generator, or the amplified signals from a microphone.

## SET UP

### Safety instructions

The demonstration oscilloscope is operated with voltages, some of which are above 60 V.

- Always turn off power supply before making connections.
- Use safety leads.

Since the glass tube is evacuated, there is an implosion hazard.

- Do not subject the tube to sharp blows or mechanical stress.

As a rule, the training oscilloscope operates at anode voltages up to about 300 V depending on what tube is connected. The anode voltage must not, however, exceed 350 V.

In schools and training institutions, operation of the device is to be responsibly supervised by trained personnel.

### To start operation

- Turn off the power supply.
- Connect the inputs of the training oscilloscope to the outputs of the power supply that supply the specified voltages (see fig. 4).
- Turn on the power supply.
- Adjust the voltage so as to not to exceed the limits.

After 10-30 sec, a green spot appears on the fluorescent screen, which denotes where the electron beam is hitting the screen. In order to keep the tube as simple and clear as possible for educational purposes, it was decided to do without additional apparatus for secondary acceleration and focusing of the beam. For this reason, it is not usually possible to focus the beam to the sharpness seen in conventional oscilloscopes.

## LIST OF EQUIPMENT

1	Training Oscilloscope	1000902 (U8481350)
1	DC Power Supply 0 – 500 V @230V	1003308 (U33000-230)
or		
1	DC Power Supply 0 – 500 V @115V	1003307 (U33000-115)
1	Function Generator FG 100 @230V	1009957 (U8533600-230)
or		
1	Function Generator FG 100 @115V	1009956 (U8533600-115)
1	Set of 15 Safety Experiment Leads, 75 cm	1002843 (U138021)

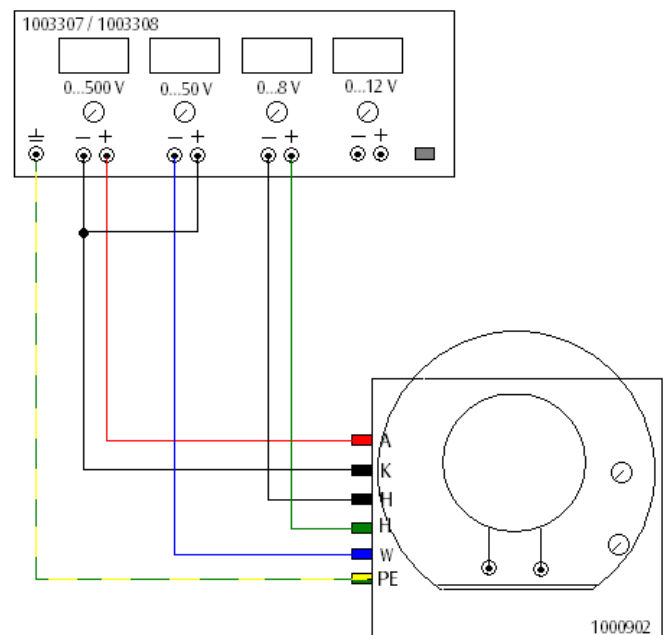


Fig. 4: Connection of training oscilloscope to power supply.

- Vary the Wehnelt voltage until the spot reaches its minimum dimensions.

The electron beam is visible as a reddish thread inside the tube, but only in a darkened room because of its low intensity.

## PROCEDURE

### Electrical deflection of the electron beam

- Turn off the power supply.
- Set up the experiment as in fig. 4.
- Connect deflecting plates to the output of the saw-tooth generator.
- Set the coarse adjustment of the saw-tooth frequency to its minimum level (second position from the left).
- Turn on the voltage supply.
- Adjust the voltage so as to not to exceed the limits (anode voltage 250 V approx.).

After 10-30 sec, the fluorescent dot appears on the screen. It should migrate periodically from left to right.

- Vary the Wehnelt voltage until the spot reaches its minimum dimensions.
- If necessary, decrease the frequency using the fine adjustment knob so that the migration of the point can be clearly tracked.

### Magnetic deflection of the electron beam

- Turn off the power supply.
- Attach a coil to the right side of the metal ring as in fig. 5.
- Set up the experiment as in fig. 5.
- Disconnect the deflecting plates from the output of the saw-tooth generator.

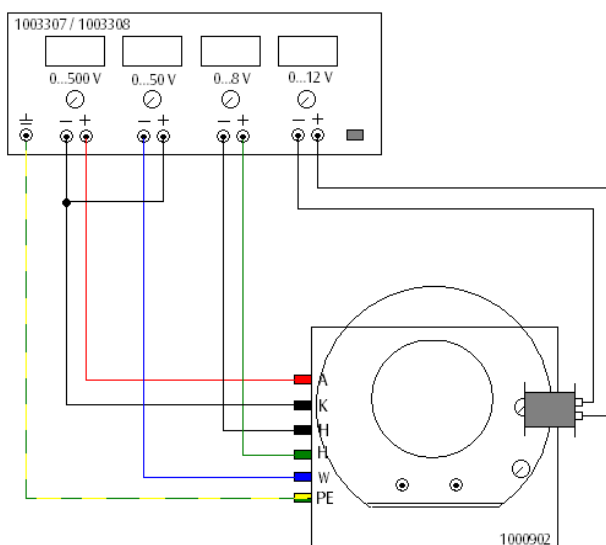


Fig. 5 Magnetic deflection of the electron beam.

- Turn on the voltage supply.
- Adjust the voltage so as to not to exceed the limits (anode voltage 250 V approx.).

After 10-30 sec, the fluorescent dot appears on the screen.

- Vary the Wehnelt voltage until the spot reaches its minimum dimensions.
- Turn on the DC power supply and vary the current to the coil.
- Change the polarity and alignment of the coil and the number of turns the current flows through and observe the effects.

### Example of oscilloscope traces: periodic signals from a function generator

- Turn off the power supply.
- Attach a coil to the right side of the metal ring as in fig. 6.
- Set up the experiment as in fig. 6.
- Connect deflecting plates to the output of the saw-tooth generator.
- Set the coarse adjustment of the saw-tooth frequency to its minimum level (second position from the left).
- Set the fine adjustment of the saw-tooth frequency " $f_{\min}$ ".
- Turn on the voltage supply.
- Adjust the voltage so as to not to exceed the limits (anode voltage 250 V approx.).

After 10-30 sec, the fluorescent dot appears on the screen. It should migrate periodically from left to right.

- Vary the Wehnelt voltage until the spot reaches its minimum dimensions.
- Select a frequency of 50 Hz on the function generator.
- Obtain the optimum oscilloscope trace by fine adjustment of the saw-tooth frequency and the function generator amplitude.

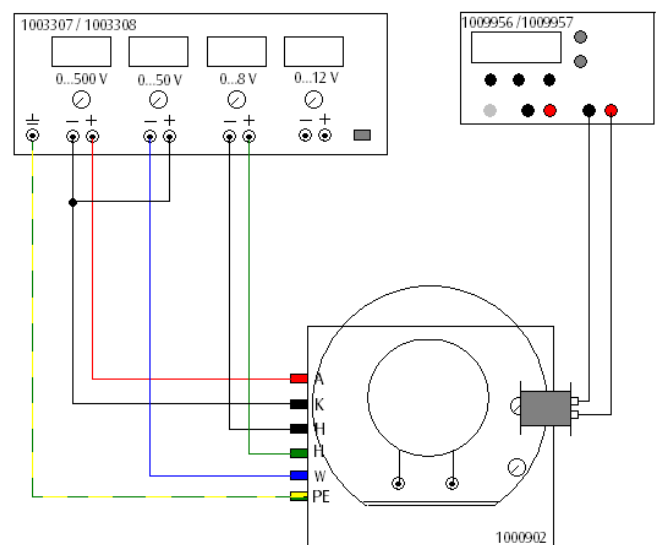


Fig. 6 Oscilloscope trace of periodic signals from a function generator.

- Repeat the experiment for a different function generator frequency, e.g. 1 kHz. Set the coarse adjustment for the saw-tooth generator to its highest level and then proceed as described for frequency 50 Hz.

#### Calibration of frequency adjustment for saw-tooth generator

- Turn off the power supply.
- Attach a coil to the right side of the metal ring as in fig. 6.
- Set up the experiment as in fig. 6.
- Connect deflecting plates to the output of the saw-tooth generator.
- Set the coarse adjustment of the saw-tooth frequency to its minimum level (second position from the left).
- Set the fine adjustment of the saw-tooth frequency " $f_{\min}$ ".
- Turn on the voltage supply.
- Adjust the voltage so as to not to exceed the limits (anode voltage 250 V approx.).

After 10-30 sec, the fluorescent dot appears on the screen. It should migrate periodically from left to right.

- Vary the Wehnelt voltage until the spot reaches its minimum dimensions.
- Select a frequency of 100 Hz on the function generator.
- With the fine adjustment, search for a frequency at which a standing image appears.

The frequency adjustment knob is now calibrated for a frequency of 100 Hz.

- Repeat the experiment for alternative frequencies.

## EVALUATION

### Electrical deflection of the electron beam

- The electron beam is deflected towards the deflecting plates.
- As a result of the saw-tooth frequency applied to the plates, the point of light periodically moves from left to right.
- If the saw-tooth frequency is increased, a continuous horizontal line of light can be seen on the screen.

### Magnetic deflection of the electron beam

- The electron beam is deflected in the vertical plane towards in the direction of magnetic field, i.e. when the coil is fitted to the right of the metal ring, the beam moves up and down.
- The direction in which this deflection occurs (up or down) is altered by changing the polarity of the DC power supply.
- The magnetic field is increased in strength by increasing the current and/or the number of coil windings through which it flows. This also increases the degree of deflection up or down.
- Changing the alignment of the coil with respect to the ring has the effect of changing the direction in which the beam is deflected. If the coil were situated at the top of the metal ring, for example, the deflection would be in a horizontal direction.

### Example of oscilloscope traces: periodic signals from a function generator

- Using the deflecting plates along with the saw-tooth generator and an alternating magnetic field around a coil connected to a function generator allows periodic signals to be displayed on the screen.
- Changing the function generator frequency requires modification of the saw-tooth frequency applied to the tube in order to obtain a trace similar to that in Fig. 1.

### Calibration of frequency adjustment for saw-tooth generator

- The frequency of the saw-tooth generator can be calibrated using the function generator. The two frequencies will be nearly identical if the oscilloscope is displaying a stationary trace on the screen.