UNIVERSIDADE da MADEIRA

Experimental Science

P5: Oscilloscope. Sensitivity, resolution and maximum device error.

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1. Purpose

- Initiation to the oscilloscope.
- Estimate the sensitivity, resolution and the maximum device error.

2. Introduction

An oscilloscope (from Latin: _oscillare_, oscillate + _skopein_, see) is a device that allows the visualisation of the variation of periodic (or repetitive) voltage signals with time. You could say it's an improved voltmeter: besides showing voltage it allows the measurement of time intervals.

Its screen is a rectangle (10 cm wide by 8 cm high) which is divided into 1 cm squares (see oscilloscope pictures at the top of pages 3 to 7). However, at the central axes of this grid there are smaller 2 mm divisions.

The oscilloscope is a transducer that can be summed up by the following diagram:

in which _x_ is the voltage U (or time interval T) and _y_ is the corresponding displacement of the screen's luminous dot.

All measurements in an oscilloscope come down to basic grid distance measurements.

If we intend to measure a voltage, the first step will be to find out how many Volts each grid centimetre is worth. This quantity is the _scale factor_. By changing the scale factor we are changing the device's _sensitivity_:

$$\text{Sensitivity} = \Delta d / \Delta U = 1/(\text{scale factor})$$

For instance, if I measured 2.4 cm in the grid and the scale selector knob indicates a scale factor of 5 V/cm, then the reading will be:

$$U = 5 \text{ V/cm} \times (2.4 \pm 0.1) \text{ cm} = (12.0 \pm 0.5) \text{ V}$$

If we intend to measure a time interval then we must know how many seconds each grid centimetre is worth.

For instance, if I measured 3.2 cm in the grid and the scale selector knob indicates a scale factor of 2 ms/cm, then the reading will be:

$$T = 2 \text{ ms/cm} \times (3.2 \pm 0.1) \text{ cm} = (6.4 \pm 0.2) \text{ ms}$$

3. Additional information

Graphical representation of a sinusoidal signal with amplitude *A* and period *T* variation over time:
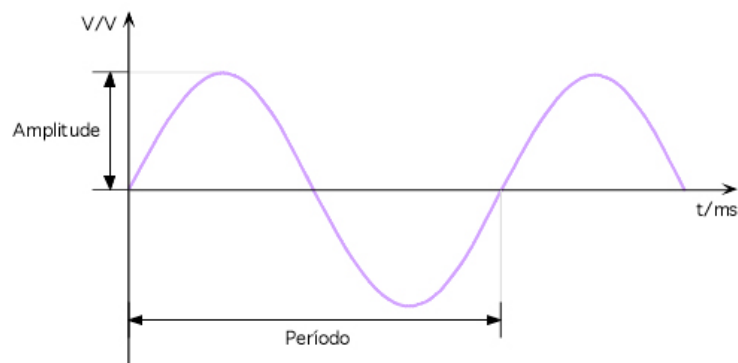
Equation:

$$V = A \sin\left(\frac{2\pi t}{T}\right)$$

4. Experimental activity

4.1 Material

1 oscilloscope, 1 signal generator, 1 voltage supply, 1 battery, oscilloscope probes, connection wires, screwdriver, crocodiles.

4.2 Experimental procedure

Read the following text and follow the indicated instructions.

On each page there is an image of an oscilloscope where you should write your own comments about each button, knob or selector used at that page.

Whenever you have to make a reading be sure to always use the most sensitive scale and to make the measurement where there are 2 mm divisions.

Always ask the teacher to confirm your measurements. Try to always organize your measurement results into tables. For each measurement, besides recording the unit you should take the maximum device error, the sensitivity as well as the resolution.
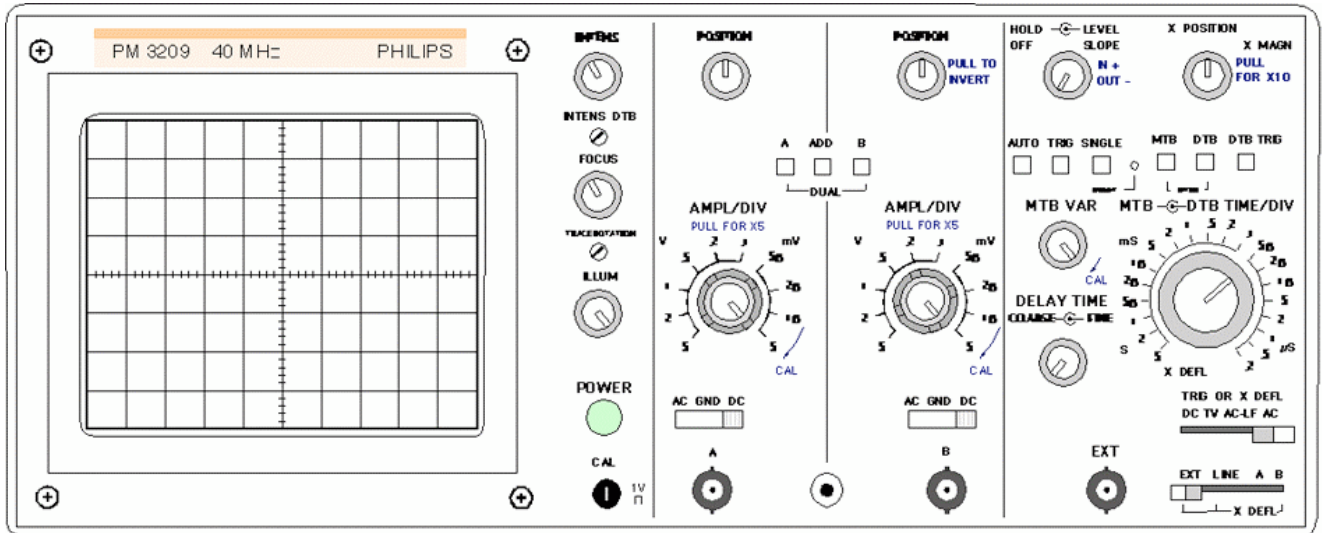
4.2.1. Inputs
a) Identify the following inputs:

> **A or I** – channel A (or I) BNC input (British Naval Connector)
> **B or II** – channel B (or II) BNC input

> **EXT** – external trigger control input

4.2.2. Outputs
a) Identify the following outputs:

> **Screen**: - 10 cm x 8 cm

>> - divided into 1 x 1 cm squares

>> - has smaller 0.2 cm divisions at the grid's central axes

> **CAL** – square signal output with 1V peak-to-peak

4.2.3. Controls
4.2.3.1 Initial checks

a) Connect the oscilloscope to a power outlet (220 V - 50 Hz)

b) Push the POWER button

c) Turn all the knobs with the CAL label to the factory calibration position (CAL)

d) Select the ground (GND) input mode. Align the sweep line with one of the horizontal grid lines. That grid line will be the 0 V reference line. Repeat for both input channels.

e) Set the trigger mode to AUTO

f) If necessary, use the screwdriver to adjust the TRACE ROTATION screw until the sweep line is aligned with the grid's horizontal lines. Repeat step d).

g) Connect one oscilloscope probe from the first channel to the CAL output.

h) Select the DC input mode.

i) Verify that the measured signal coincides with the nominal calibration signal. Don't forget to use the appropriate scale factor and record your measurements.
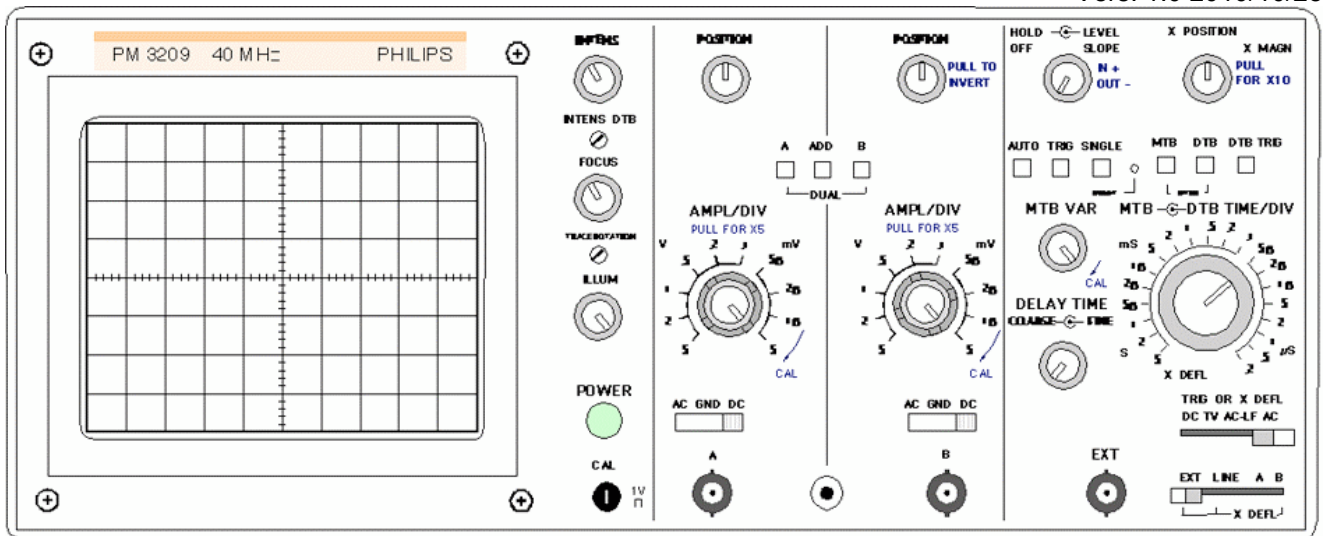
4.2.3.2 Screen controls

    a) Test each of these parameters and verify their function:

INTENS - controls the intensity of the sweep line

FOCUS – controls the electrons beam convergence towards the screen. It is used to make the sweep trace sharper.

TRACE ROTATION – controls the direction of the sweep trace. The sweep trace should be parallel to the grid's horizontal lines.

ILLUM – Offers the possibility of a backlight screen. It should be used when measurements are made in low light conditions or to take screen pictures.
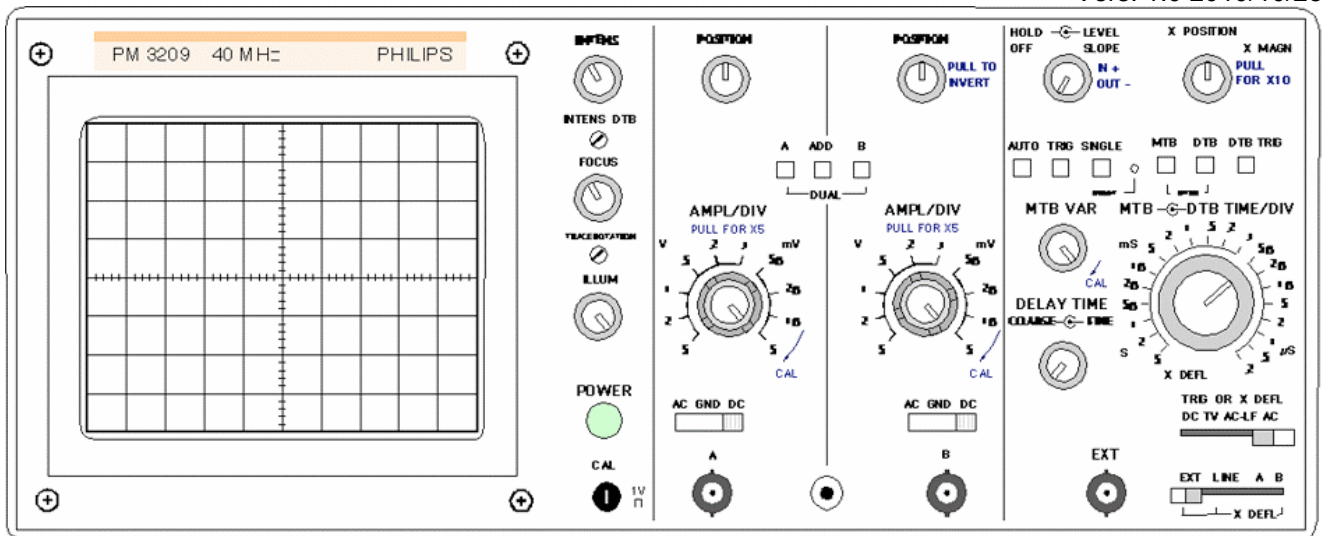
4.2.4 Vertical deflection control

a) Identify the following controls:

AMP/DIV - Outer: deflection coefficient selector from 5 mV/div to 5 V/div

- Inner: deflection coefficient re-calibrator. Should be at the CAL position for the factory calibration.

- When the inner deflection control is pulled the vertical deflection coefficient increases by a factor of 5.

b) Use the first channel probe to measure the battery voltage. Use the second channel probe to measure and set a different voltage at the voltage supply. Record the measurements in a table. Extend the table by adding three different voltage supply output values.

c) Make sure that for a 0 V input the measured value is in fact 0 V (zero adjust). How can a zero adjust be made without disconnecting the probe from the voltage supply?

d) Connect one of the probes to the oscilloscope's CAL output signal and pull the inner vertical deflection control. What happened? Reconnect the probes as they were at b).

e) Test each of the following parameters:

POSITION – controls the vertical position of the sweep line.

AC GND DC – input connection selector:

AC – on this operation mode any constant signal component is removed
DC – the input signal is directly connected to the vertical deflection plates
GND – the vertical deflection plates are short-circuited

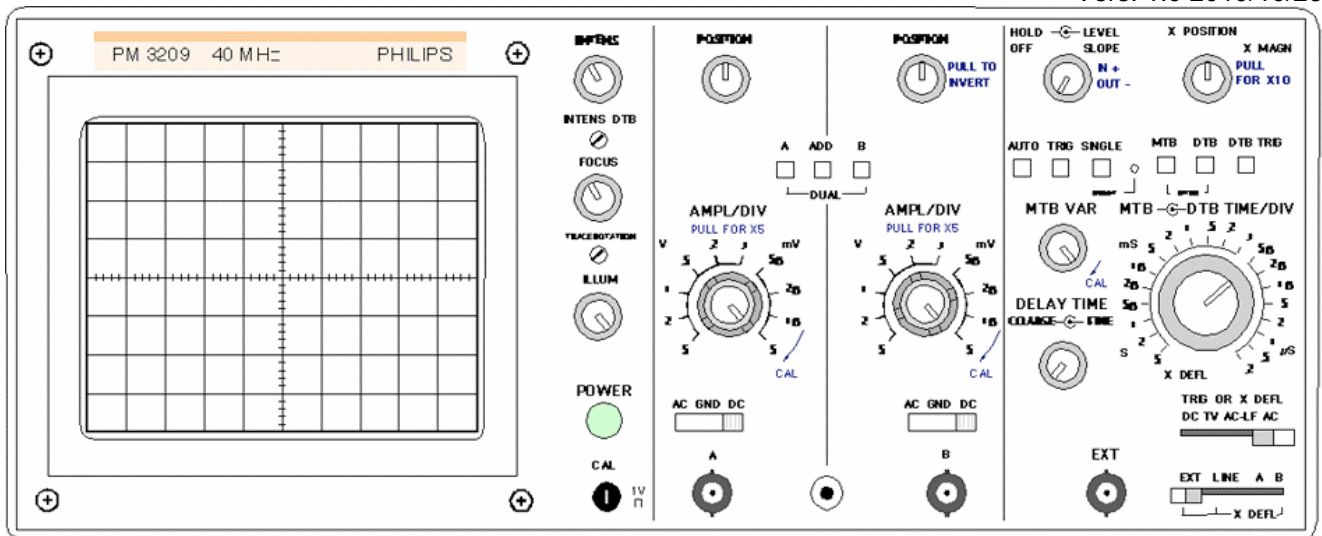**A ADD B** – visible channels selector:

A – only the A channel is visible

B – only the B channel is visible

DUAL – both channels A and B are visible
0.2 µs/div – 0.5 ms/div – ALT mode;   1 ms/div – 0.5 s/div – CHOP mode
ADD – displays A+B or A-B

5/7

4.2.5 Horizontal deflection control
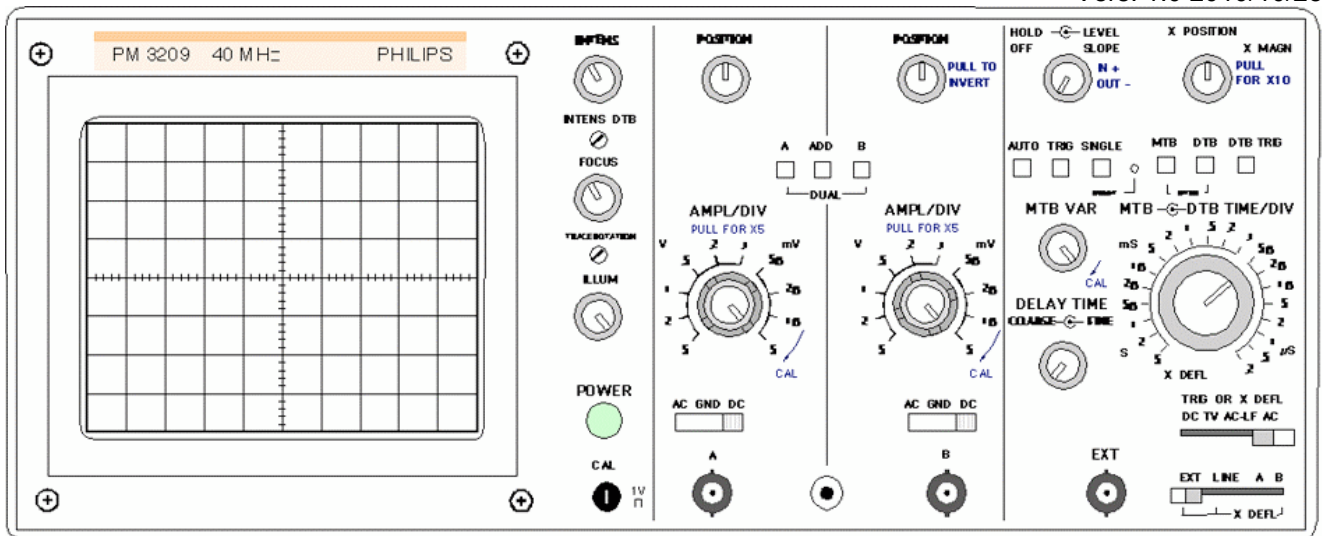
a) Identify the following controls:

> **MTB TIME/DIV** - Outer: main time base deflection coefficient (sweep speed) selector from 0.2 μs/div – 0.5 ms/div
>
> **MTB** – main time base selector
>
> **X DEFL** – a complete counter clockwise rotation of the MTB TIME/DIV selector sets the X-Y mode
>
> **MTB VAR** – main time base re-calibrator

b) Connect the 10x selected probe to the CAL oscilloscope output. Change the probe to the 1x setting and pull the x-position knob. What happened?

c) Reset the x-position knob to the original position and set the probe back to 10x. What happened?

d) Remove the voltage supply connections. Connect the signal generator output to the A channel oscilloscope input. Measure the sinusoidal signal amplitude and period. Repeat for 4 different sets of amplitude and period. Organize your results into a table.

4.2.6 Trigger system

a) Identify the following oscilloscope controls:

AUTO – The sweep is automatic and takes place even when there is no signal.

TRIG – The sweep only happens when two criteria are met: The voltage level is greater than a preset value and the voltage slope over time has a preset sign (+/-).

SINGLE – Only a single sweep happens.

LEVEL – Voltage level selector. When the input voltage is larger a sweep is triggered.

SLOPE – slope sign selector (can take only two possible values: + or -).

SOURCE – trigger signal source selector used to evaluate if a sweep should be triggered (level and slope criteria are met). There are 4 possible sources:

A – the A channel
B – the B channel
EXT – an external signal is applied to the "EXT" input
LINE – the AC network power (220 V, 50 Hz)

b) In the AUTO trigger mode, connect channels A and B to two independent signals (use the signal generator and the CAL signal output). Observe both signals simultaneously. Watch what happens when different trigger sources are selected (A, B, EXT or LINE). Record the signal shapes (with scale factors). Explain what you observe.

c) Change to the TRIG mode and see what happens at the sweep beginning. What is the sweep initiation voltage level? What is the slope sign? Rotate the LEVEL knob and explain what you observe. Pull or push the knob and explain what you observe.