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LABORATORY OF MEASUREMENTS

LABORATORY EXPERIMENT No **2**

Digital Oscilloscope for engineering measurements

Goal:

The main goal of the experiment is to familiarise students with use of a digital oscilloscope for engineering practice especially for identification of parameters of electrical signals.

SPECIFICATION OF USED INSTRUMENTS:

The following instruments and software are used:

Instruments

1. Digital Oscilloscope RIGOL DS1052E
2. Digital Signal generator DDS DF1410
3. A set of frequency reference etalons

Software:

1. Software DATA4711 to control generator DS1307
2. ULTRASCOPE, a program to operate DS1000E oscilloscope
3. Program to generate sine wave function for LISSAJOUS presentation
4. Microsoft Office Excel to handle data collected from instruments

THEORY

INTRODUCTION

Signals are analogue or digital electrical representations of time-varying or space-varying physical quantities. Signals exhibit diversity in function and structure. The two main ways of describing signals concentrate either upon their time domain properties or their frequency domain properties. A complete time-domain description of a sine signal can be represented by:

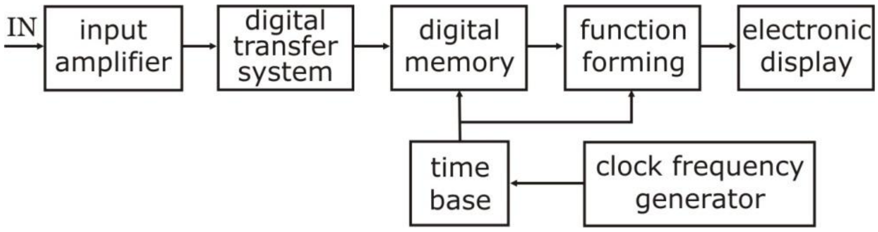
$$x(t) = x(t + kT)$$

where: T – period of the signal.

To visualise and identify parameters of electrical signals the oscilloscopes are used commonly.

An oscilloscope (referred to as a scope for short) is a universal measuring instrument capable of measuring a variety of rapidly changing electrical signals.. The oscilloscope displays graphs of voltage against time. Nowadays, oscilloscope is one of the most versatile and widely used electronic instruments for measurement and diagnostic purposes. It is used to diagnose electronic systems and characterize parameters of electrical signals. The digital oscilloscope offers a recording of sampled signals, mathematical operation on signals and the Fourier analysis. Most oscilloscopes can be operated by computers via USB interface. Sampled signals and their parameters can be recorded and saved in the form of files. Image from oscilloscope screen can be transferred to computer for further analysis.

The block diagram of a digital oscilloscope is shown in figure below. The analogue signal passes through an instrumental amplifier to digital transfer system, in which signal is sampled and quantised, and transformed into digital form. The frequency of sampling depends on the range of the time base, which is synchronised by the clock.



The block diagram of digital oscilloscope

PARAMETRES OF DIGITAL OSCILISCOPE

The basic critical block of digital oscilloscope from the point of view of its parameters, is a block which includes analogue-to-digital converter(ADC).

Sampling frequency of ADC is expressed in hertz (1MHz = 10^6Hz, 1 GHz = 10^9Hz) or as number of samples per second (Sa/s, S/s called Samples per second). In today's digital oscilloscopes, sampling frequency is not less than 100 MHz (100 Ms/s), max now can be 80 GSa/s. The sampling frequency is closely related to the frequency bandwidth defined as the transmission frequency bandwidth limit. The frequency limit is always at least several times smaller than the sampling frequency. The typical frequency limits are in the range of 20MHz to 30GHz.

All technical parameters of the oscilloscope can be divided into the following groups:

- horizontal parameters - time base parameters
- vertical parameters (enhance performance)/ time-base sensitivity of the oscilloscope
- trigger parameters of the system (called trigger parameters);
- acquisition parameters,
- measurement features
- other parameters

Time-based parameters:

- the maximum sampling frequency
- record size memory for storing samples (MPTS / CH; kPts / CH) is expressed as the number of points (samples) per channel,
- adjustable time base range
- type of adjustable time base: displacement (not continuous) / continuous
- the maximum size of registered record of data at the maximum sampling frequency,
- trigger delay of ADC,
- range of horizontal adjustment.

Parameters strengthening - sensitivity:

- the number of input channels

- limits of channel bandwidth (3dB attenuation)
- input impedance,
- bit resolution - amplitude resolution,
- vertical sensitivity (sensitivity to voltage amplitude) - range of adjustable sensitivity
- offset adjustment (displacement range)
- the type of amplification adjustment displacement (non continuous) / continuous
- the maximum input voltage

<u>Trigger parameters :</u>

- trigger modes: Auto / manual / one-off,
- methods of triggering: slope, level, the logical state, pulse width, input signal, a sequence of logic, algebraic condition signals in various channels
- type of component signal triggering DC, AC + DC, AC with filtration,
- the range of adjustment of the trigger condition at the time
- adjustment time range of inactivity trigger condition (called hold off)
- the range of time delay trigger condition,

<u>Acquisition Parameters:</u>

-normal acquisition mode - direct sampling of the ADC,
- peak Detect acquisition mode - transient signal changes,
- average acquisition mode - sequences of samples averaged,
- roll mode acquisition with continuous scrolling image
- LowRES/HighRES acquisition of samples with low/high frequency sampling.

<u>Measuring functions:</u>

- the accuracy and range of measurement cursors,
- the features of automated measurements of parameters of signal,
- modes to limit the scope of automated measurement,
- operators and functions of mathematical analysis performed on the signals.

<u>Operating parameters:</u>

- size, resolution matrix LCD oscilloscope
- refresh rate of progress,
- communication interfaces,
- types of battery power / network
- additional features self-diagnostics, auto-calibration, etc.
- the Standard Commands for Programmable Instruments **(**SCPI**) -** communication protocol.

"Final remarks" section delivers oscilloscope specification used in the experiment.

PRINCIPLE OF DIGITAL OSCILLOSCOPE OPERATION

In order to record and display a waveform, please adjust the oscilloscope settings. If the parameters such and frequency and amplitude of the waveform under test are known, then the oscilloscope settings can be selected so as to obtain the best possible picture displayed. For this purpose, please adjust the following settings:

1st Horizontal scale setup (time base)

Adjusting the time base changes the time period in which the waveform is observed. The time range of the oscilloscope screen depends on the product of the number of divisions on OX axis, and the time base setting (s/div).

2nd Vertical scale setup (signal amplitude sensitivity)

Gain control signal (changes the gain / attenuation of the signal fed to the input). Range of the oscilloscope amplitude is equal to the product of the number of divisions on vertical axis (OY direction) and gain setting (Volts/Div setting).

3rd Trigger setup (trigger system)

Trigger system settings allows periodic signals to be displayed as stable waveform. The system is to capture and display the relevant parts of the waveform in the case of non-periodic waveforms, or catch anomalies in the waveform.

Triggering signal can become a signal under test itself, or other channel or externally, if “EXT TRIG” input is fed. Triggering options are: rising or declining edge (called edge rise/fall), impulse, algebraic condition such as greater than / less than / equal to. If the level of voltage trigger source and trigger are already fixed, the next step is to choose single or permanent triggering by setting: single mode / normal, or Auto mode with a specific delay called Holdoff.

If parameters of the waveform under test are not known, the use of auto setting function for all parameters (AUTO) is recommended. Auto button of the oscilloscope sets up VERTICAL, HORIZONTAL and TRIGGER controls to display input signal.

The location of the knobs and information tags in the window of a typical oscilloscope is illustrated in Fig. 1 and Fig. 2 (in blue frames with an English and Polish language description of the oscilloscope menu).

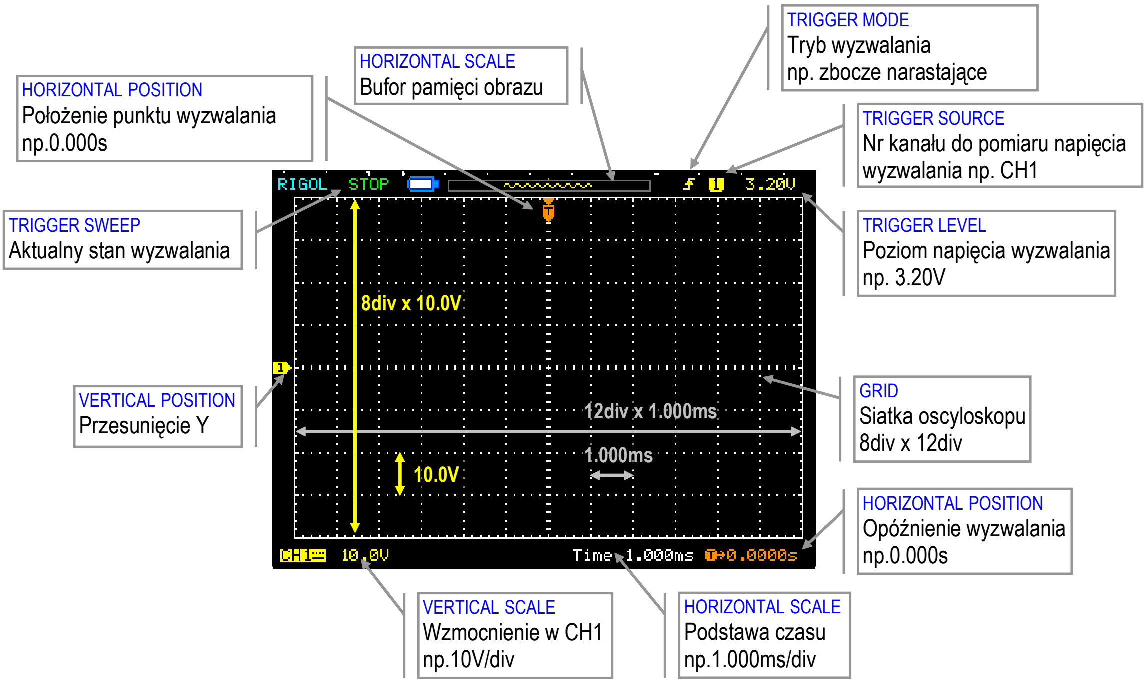


Fig.1 View of a typical oscilloscope display window with grid and settings of controls.

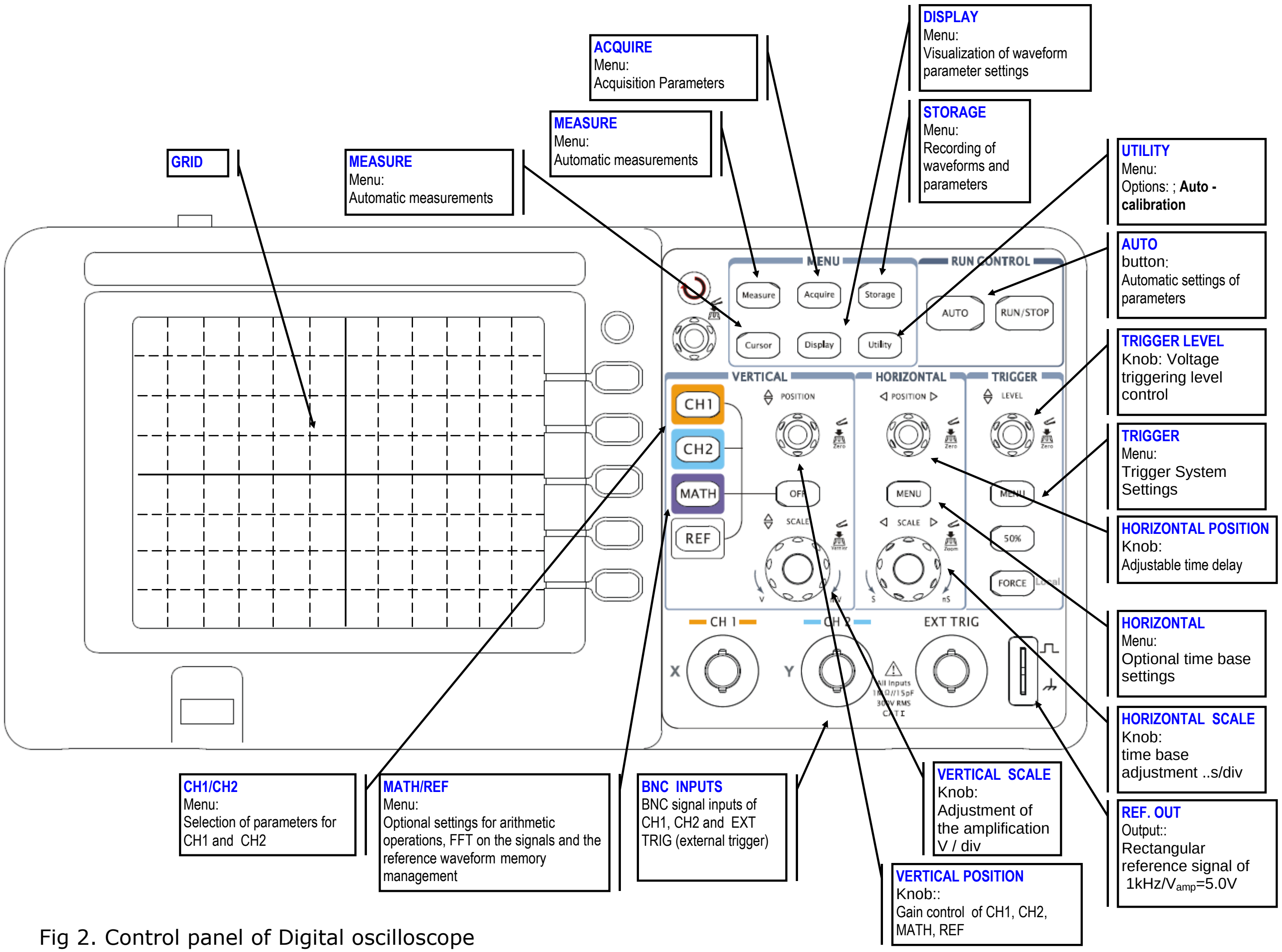


Fig 2. Control panel of Digital oscilloscope

MEASUREMENTS USING OSCILLOSCOPE

1. Measurement of voltage and electrical signal parameters.

In order to measure the amplitude and the other parameters of signals, the signal under test, is set to input of ch1 or ch2 (BNC type connector). Then the location of reference "zero" is specifies, using options in the menu CH1/COUPLING-> GND and adjusting the position of the curse of the HORIZONTAL POSITION knob. Next, by changing the time base settings and trigger settings choose the best possible picture of the screen. Measurement of signal parameters can be performed using three methods:

A) Direct reading of parameters of the waveform signal from grid and oscilloscope setting: (Fig. 3). The grid scale divides evenly oscilloscope screen window in both directions. Rigol window has eight vertical divisions (div) and 12 horizontal divisions (div). Amplitude Multiplying the number of divisions (*n*) from grid scale by vertical gain setting expressed in V/div) the amplitude in volts equals to:

$$V_{\mathrm{Y}} = n_{\mathrm{DY}}[\mathrm{div}] \cdot Vertical_{\mathrm{SCALE}}[\mathrm{V/div}] \tag{1}$$

Baseing on Horizontal scale setting (s/div) and number of divisions covering time period a period of the signal in seconds equals to:

$$t_{\mathrm{X}} = n_{\mathrm{DX}}[\mathrm{div}] \cdot \mathrm{Horizontal}_{\mathrm{SCALE}}[\mathrm{s/div}] \tag{2}$$

where:

n_{DX} – number of divisions [div] equivalent to time to be measured OX (time axis)

n_{DY} – number of divisions [div] equivalent to amplitude to be measured OY (amplitude axis)

$Horizontal_{\mathrm{SCALE}}$ – time base set-up (s/div)

$Vertical_{\mathrm{SCALE}}$ – gain set-up (V/div)

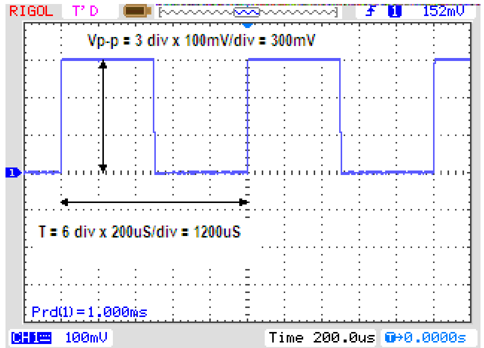
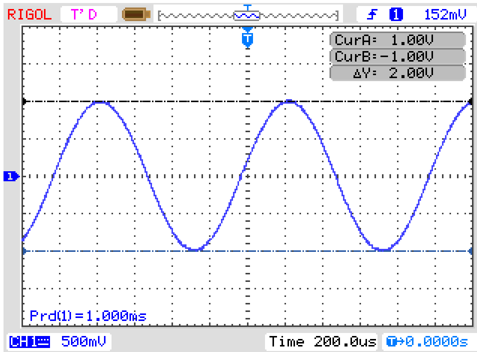


Fig 3. Example of measurement based on direct reading from oscilloscope grid

B) The signal parameters can be determined using the measurement cursors available from the CURSOR menu. With two cursors (CurA, CurB), for X and Y axis, the measured values are displayed on a screen (Fig. 4a and 4b)

a) 

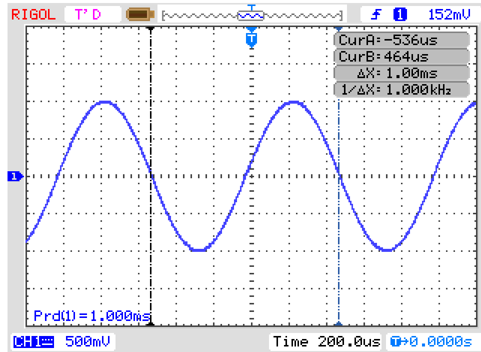
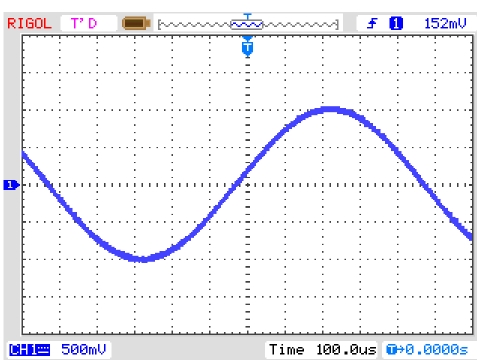
b) 

Fig.4 a) Example of peak-to-peak voltage measurement V_{p-p} using OY CURSOR; b) T – period of waveform measurement be using OX CURSOR

C) The third method is to use automatic measurement function. To activate of automatic measurement mode use button from menu MEASURE. Amplitude (V_{AMP}), peak-to-peak (V_{P-P}), Maximum value (V_{MAX}), minimum value (V_{MIN}), average (V_{AVG}), RMS value (V_{RMS}), period (T_P), frequency (f), raising time (t_R), falling time (t_F), pulse width in low state (t_L), pulse width in high state (t_H), duty cycle (C_D), time delay (t_D), are displayed.

The averaging function is used to reduce noise or unwanted disturbances influencing measured waveform. Averaging is done over the required number of samples the choice of which is availed from: ACQUIRE/ACQUISITION->AVERAGE. The effect of averaging presented in FIG. 5b AVERAGE (after averaing) while Fig. 5a presents waveform without averaging (NORMAL).

a) 

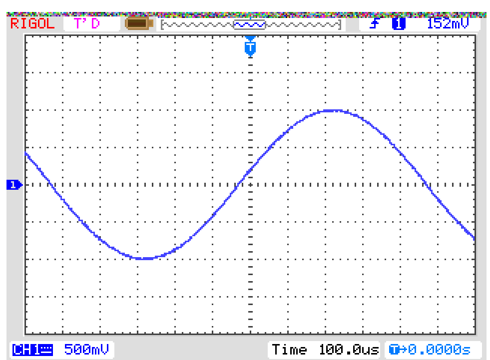
b) 

Fig.5. Graph of the waveform under test a) NORMAL mode
b) AVERAGE mode (after averaging from 256 samples)

1. The Phase Shift measurement

The basic methods of measuring the phase shift between two harmonic signals of the same frequency are:

1st direct method (method based on shift transformation in time interval)

2nd Lissajous patterns method based on ellipse shape

3rd Compensation method,

1st direct method

This method is based on time measurement and conversion a time period to expressed in seconds to angle expressed in deg or radians proportionally (Equ 3). The phase shift between two signals is presented in Fig.6.

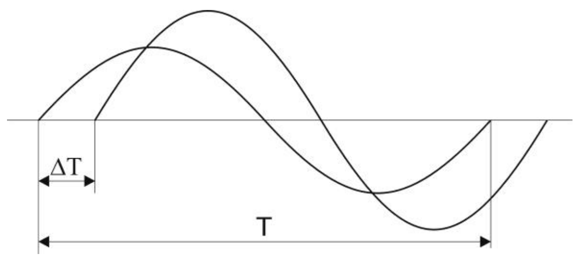


Fig. 6. The method of transformation in the time interval

Phase shift conversion from time domain to radians is given by (3)

$$\varphi = 2\pi \frac{\Delta T}{T} \ , \tag{3}$$

where:

ΔT - time difference between to moments when two waveforms are crossing horizontal axis,

T - period of the waveform.

2nd Lissajous patterns based method

Ellipse method is based on measurement the dimensions of the ellipse which is formed by two signals applied to two channels of the oscilloscope in X-Y mode of the oscilloscope. The signals applied to both inputs must be of the same frequency.

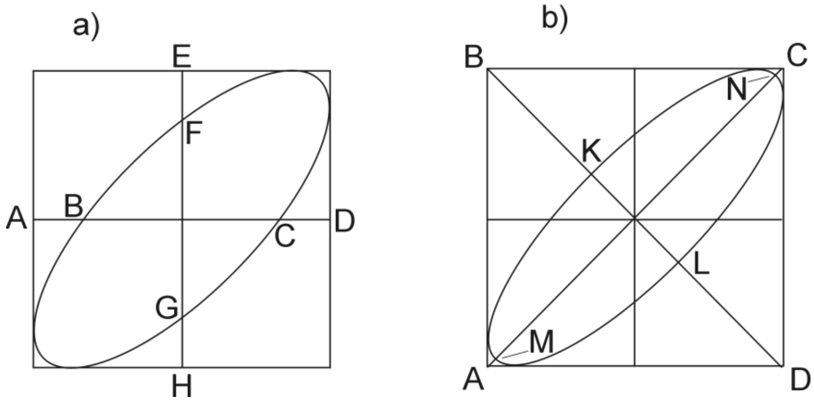


Fig. 7. Ellipsoid Phase Shift measurement method for a) larger value of the shift and (b) smaller values of the shift

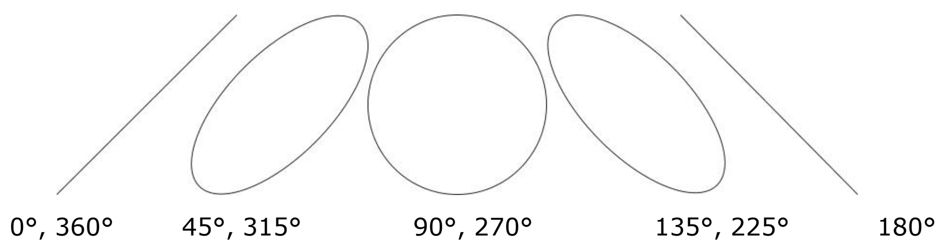


Fig. 8a . Ellipsoid Phase Shift measurement method for different phase shifts,

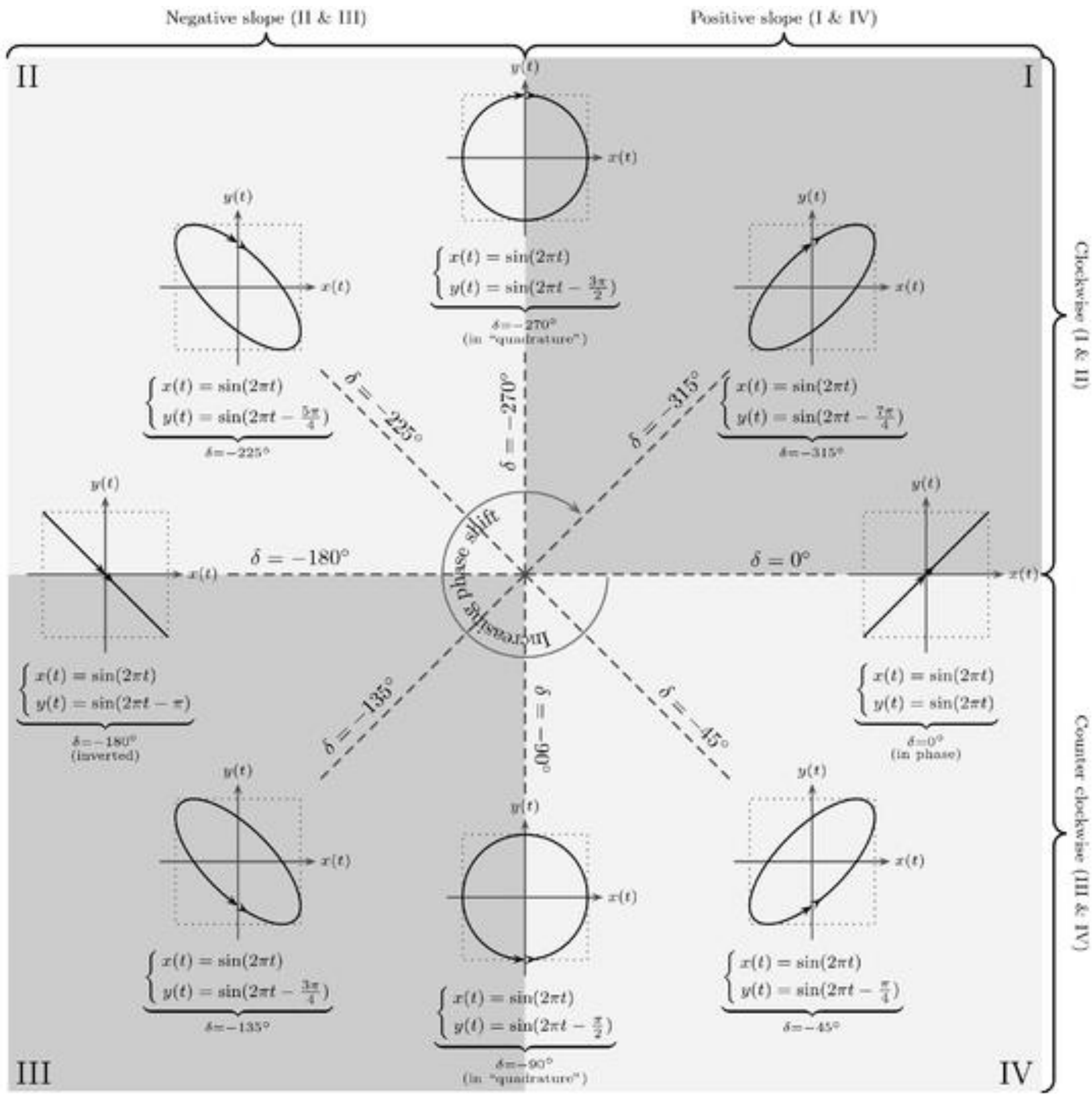


Fig. 8b . Ellipsoid Phase Shift measurement method for different phase shifts,

Based on measurements of sections on 0Y axis of ellipse, the following relation is valid.

$$\sin\varphi = \frac{FG}{EH}. \tag{4}$$

And for 0X axis:

$$\sin\varphi = \frac{BC}{AD}. \tag{5}$$

Phase value φ expressed as angle can be calculated by (6):

$$\varphi = \arcsin \frac{FG}{EH} = \arcsin \frac{BC}{AD} \tag{6}$$

Relative measurement error, $\delta\varphi$, can be calculated based on partial derivative given by (9) for which the accuracy of distanced points on the ellipse is limited by $\Delta FG = \Delta EH = 0{,}1$ division. So:

$$\delta FG = \frac{\Delta FG}{FG} \cdot 100\,\% \tag{7}$$

$$\delta EH = \frac{\Delta EH}{EH} \cdot 100\,\% \tag{8}$$

and

$$\delta\varphi = \left| \frac{FG \cdot \delta FG}{EH\sqrt{1-\left(\frac{FG}{EH}\right)^2} \arcsin \frac{FG}{EH}} \right| + \left| -\frac{FG \cdot \delta EH}{EH\sqrt{1-\left(\frac{FG}{EH}\right)^2} \arcsin \frac{FG}{EH}} \right| \tag{9}$$

The above method is suitable for larger shift: $\varphi > \frac{\pi}{3}$.

If the angle φ is very small, more accurate result can be obtained by applying formula (10).

$$tg\,\frac{\varphi}{2} = \frac{KL}{MN}\ , \tag{10}$$

therefore:

$$\varphi = 2 \cdot arctg\,\frac{KL}{MN} \tag{11}$$

or applying (12) in which points of ellipse are as in Fig 7b).

$$\varphi = \arcsin \frac{KL}{AD}\frac{MN}{CD}\ . \tag{12}$$

A condition that must be fulfilled in the method of the ellipse is equal amplitudes along the two axes, namely AB = AD. Both presented methods for determining the phase angle involving ellipse are rather of low accuracy: the result is expected to be within a few %. Error is caused by:

- Not accurate measurement of separation between points on the ellipse,
- The finite thickness of the line representing ellipses on the screen,
- uncompensated parasitic phase shifts,
- inaccurate setting of equality of both amplitudes.

3 rd Compensation method

The method is based on compensation of phase shift between two harmonic signals using calibrated phase shifter to archive 0 shift or complement to 2π. Oscilloscope is used as indicator of compensation achieving. The compensation phase α is read on the scale of phase shifter. If straight line is inclined to the right then compensation is $\varphi = -\alpha$, if inclined to the left then compensation is $\varphi = \pi - \alpha$

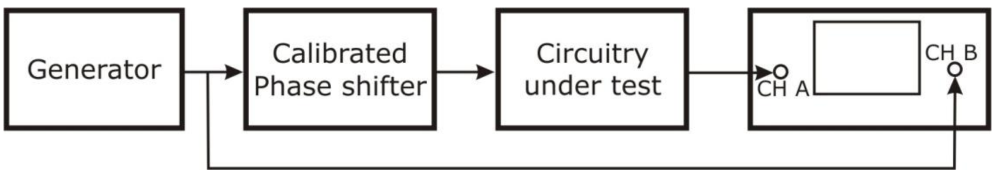


Fig. 9. Block diagram to measure phase shift applying compensation method

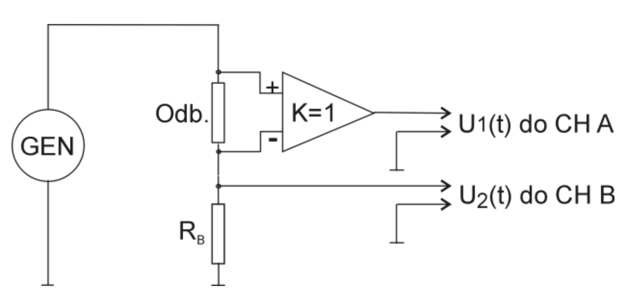
2. Electrical power measurement using oscilloscope

There are several methods of the electrical active power measurement of small values (of the order mW) for a wide frequency range, limited by the bandwidth of used oscilloscope. These methods are primarily based on semi bridge method using an additional resistor or capacitor. In such cases, the power output is calculated from the surface of the ellipse.

Modern digital oscilloscopes allow for more accurate measurement of low power in a wide range of frequencies. The possibilities of digital signal processing by the oscilloscope are Used in this case. Power can be defined as the average instantaneous power for a period of change (13).

$$P = \frac{1}{T}\int_0^T u(t) \cdot i(t) dt \tag{13}$$

If one signal, proportional to voltage, and the other proportional to current, of a two terminal element, of which active power is to be measured, using mathematical function _ multiplication of two signals CH1xCH2 and averaging, then the result is proportional to the active power (Fig. 10.).



Figs. 10 Electrical scheme to measure active power using oscilloscope – method suitable for rather small values of active power, but rather high bandwidth

EXPERIMENT:

TASK 1:

Setting up oscilloscope, auto calibration oscilloscope testing by reference signals

1. Basic oscilloscope settings as follows:
   - Set up the smallest gain 10V/div SCALE ↕
   - Set up time base to 1ms/div SCALE ↔
   - Set up shifts of X, Y inputs of signals centrally against screen grid VERTICAL POSITION, HORIZONTAL POSITION
   - Switch off (if active): channel 2 CH2, operations MATH, and leave REF on and leave active CH1
   - Switch off (if active): horizontal and vertical CURSOR
   - Switch off (if active): data from automatic MEASURE
   - Set up parameters of measurement probe (attenuation) CH1/PROBE
   - Set up DC on Channel 1: CH1/COUPLING->DC
   - Switch off (if active): bandwidth limitation CH1/BW LIMIT->OFF
   - Switch off (if active): digital filters CH1/DIGITAL FILTER->OFF
   - Switch on: auto trigger: TRIGGER/SWEEP->AUTO
   - Switch on: source of triggering signal to CH1: TRIGGER/SOURCE->CH1
2. Complete calibration function: UTILITY/SELF-CAL.
3. Check the oscilloscope using reference internal oscilloscope signal to input CH A

Connect (wire) the output of internal source of reference signal to CH A input and check correctness of gain and time base of oscilloscope settings against reference parameters

Rectangular reference signal parameters: frequency of 1kHz and amplitude V_{amp}=5.0V

Measurements record in table 1.

Table 1. Reference signal measured by oscilloscope: (rectangular pulse train signal). V_{AMP}-amplitude, V_{P-P} – peak to peak, f – frequency, T – period, D – duty cycle

V_{AMP}	V_{P-P}	f	T	D
V	V	Hz	ms	%

$D = \frac{T_1}{T}$ where: T1 is a duration when the function is active; T is a period of the function

TASK 2

Electrical signal parameter measurements

Connect the output of DF1410 generator to CHA input using a wire with BNC connector (Bayonet Neill–Concelman or British Naval Connector).

Perform measurements of parameters of 3 different signals (sine wave, triangle wave and square wave) and complete Tables 2, 3 and 4 with relevant data.

Measurements for two modes of data acquisition: NORMAL and AVERAGE (256 averaged samples).

Record image of screen using a function from menu STORAGE/BITMAP, or the software ULTRASCOPE FOR DS1000E.

Table 2. Measurements of parameters of the signal No 1

signal No 1 sine waveform					
Data acquisition mode	Type of measurement	V_{AMP}	V_{P-P}	f	T
-	-	V	V	Hz	ms
NORMAL mode	**Direct** – reading from screen using cursors				
NORMAL mode	**Automatic** use Measure function				
AVERAGE of 256 Sa (acquire))	**Direct** – reading from screen using cursors				
AVERAGE of 256 Sa (acquire)	**Automatic** use Measure function				

NOTE: AVERAGE of 256 Sa = measure after averaging of acquired of 256 Samples

Table 3. Measurements of parameters of the signal No 2

signal No 2 triangle waveform						
Data acquisition mode	Type of measurement	V_{AMP}	V_{P-P}	f	V_{AVG}	V_{RMS}
-	-	V	V	kHz	V	V
NORMAL mode	**Direct** – reading from screen using cursors					
NORMAL mode	**Automatic** use Measure function					
AVERAGE of 256 Sa (acquire)	**Direct** – reading from screen using cursors					
AVERAGE of 256 Sa (acquire)	**Automatic** use Measure function					

Table 4. Measurements of parameters of the signal No 3

signal No 3 square waveform						
Data acquisition mode	Type of measurement	V_{P-P}	T	t_R	t_F	f
-	-	V	ms	ms	ms	Hz
NORMAL mode	**Direct** – reading from screen using cursors					
NORMAL mode	**Automatic** use Measure function					
AVERAGE of 256 Sa (acquire)	**Direct** – reading from screen using cursors					
AVERAGE of 256 Sa (acquire)	**Automatic** use Measure function					

TASK 3

Phase shift measurement

Connect both outputs of PCI sound card Input of CH 1 and CH 2 of the oscilloscope. The computer sound card generates signals at both outputs according to data procuced by "Lissajous" software package.

Please perform measurements of Phase between two signals for 90 and 45 deg between them. Parameters of generated signals are given in tab. 5.

Table 5. Parameters of tested signals

Parameter	First set of signals		Second set of signals	
	Signal 1	Signal 2	Signal 1	Signal 2
Frequency [Hz]	2000 Hz	2000 Hz	2000 Hz	2000 Hz
Level of the signal [dB]	6 dB	6 dB	6 dB	6 dB
Initial phase of each signal	φ_{01}[°] = 0 deg	φ_{02}[°] = 90 deg	φ_{01}[°] = 0 deg	φ_{02}[°] = 90 deg
Phase shift between signals from channel 1 and 2	$\varphi = \varphi_{01} - \varphi_{02}$ [°]90 deg		$\varphi = \varphi_{01} - \varphi_{02}$ [°]90 deg	

There are two methods of phase shift measurement using oscilloscope provided in the experiment.

1st – direct.

The phase relation between two sinusoids may be directly measured by viewing both waveforms on oscilloscope and determining the delay time t_d between two waveforms. The scope is set to alternate mode (for viewing two waveforms simultaneously), with each vertical amplifier sensitivity and trigger control adjusted for two stationary sinusoids.

The phase is determined by

$$\varphi(\deg) = \frac{\Delta T}{T} \cdot 360 \quad and \quad \varphi(rad) = \frac{\Delta T}{T} \cdot 2\pi$$

Measurements record in table 6.

Table 6. Phase shift measurement results and calculations (Fig.6, Equation (3))

First set of signals Signal 1			
Phase φ between Signal 1 and signal 2			
ΔT	T	φ	
s	s	rad	deg

Second set of signals			
Phase φ between Signal 1 and signal 2			
ΔT	T	φ	
s	s	rad	deg

2nd – Lissajous patterns.

A second method for determining the phase shift is to feed one sinusoid into the vertical amplifier, with the other connected to horizontal input. In this case set mode to x-Y display

The phase according to Fig. 6 is determined by

$$\varphi = \arcsin\frac{FG}{EH} = \arcsin\frac{BC}{AD} \qquad \varphi = \arcsin\frac{KL}{AD}\frac{MN}{CD}$$

Measurements record in table 7.

Table 7. Phase shift measurement results and calculations

First set of signals Signal 1		
Phase φ between Signal 1 and signal 2		
Fig. 7a		
FG	EH	$\varphi = \arcsin\frac{FG}{EH} = \arcsin\frac{BC}{AD}$
div	div	deg

Second set of signals		
Phase φ between Signal 1 and signal 2		
Fig. 7a		
FG	EH	$\varphi = \arcsin\frac{FG}{EH} = \arcsin\frac{BC}{AD}$
div	div	deg

Please apply a remote control of the oscilloscope from PC computer.

Compare measurement results to parameters declared in the programme LISSAJOUS

TASK 4

Recording and processing of data using oscilloscope communication interfaces

By using the oscilloscope STORAGE, record the data set using the oscilloscope function STORAGE/CSV file. Saving data in a file with the extension *. CSV (Comma Separated Values) you can edit it in a spreadsheet. Please use the drawing function graphs in a spreadsheet illustrating the stored process. You must configure the settings of the chart (the number of horizontal lines and vertical grid, scale, axis) in such a way that would comply to the grid scale of the oscilloscope window. In order to compare, record a screenshot apply STORAGE/BITMAP oscilloscope facilities.

DS 1052 SPECIFICATION

Acquisition			
Sampling Modes	Real-Time	Equivalent	
Sampling Rate	1GSa/s, 200MSa/s[1]	DS1102X 25GSa/s	DS1052X 10GSa/s
Averages	N time acquisitions, all channels simultaneously, N is selectable from 2, 4, 8, 16, 32, 64, 128 and 256.		

Inputs	
Input Coupling	DC, AC, GND
Input Impedance	1MΩ±2%, in parallel with 15pF±3pF
Probe Attenuation Factors	1X, 5X, 10X, 50X, 100X, 500X,1000X
Maximum Input Voltage	400V (DC＋AC Peak, 1MΩ input impedance)
	40V (DC+AC Peak) [1]
Time delay between channel (typical)	500ps

Horizontal				
Sample Rate Range	Real-Time: 13.65Sa/s-1GSa/s Equivalent: 13.65Sa/s-25GSa/s			
Waveform interpolation	Sin(x)/x			
Record Length	Channel Mode	Sample rate	Record Length (normal)	Record Length (long record)
	Single channel	1GSa/s	16Kpts	N.A.
	Single channel	500MSa/s Or lower	16 Kpts	1Mpts
	Double channel	500MSa/s Or lower	8 Kpts	512Kpts
Scan speed Range (Sec/div)	2ns/div~50s/div, DS1102X 5ns/div~50s/div, DS1052X 1-2-5 Sequence			
Sample Rate and Delay Time	±50ppm (over any 1ms time interval)			

Accuracy	
Delta Time Measurement Accuracy (Full Bandwidth)	Single-shot: ±(1 sample interval + 50ppm × reading + 0.6 ns) >16 averages: ±(1sample interval + 50ppm × reading + 0.4 ns)

Vertical	
A/D converter	8-bit resolution, each channel samples simultaneously[2]
Volts/div Range	2mV/div~10V/div at input BNC CONNECTOR
Maximum Input	Analog channel maximum input voltage CAT I 300Vrms, 1000Vpk；instantaneous voltage 1000Vpk CAT II 100Vrms， 1000Vpk RP2200 10:1：CAT II 300Vrms RP3200 10:1：CAT II 300Vrms RP3300 10:1：CAT II 300Vrms
Offset Range	±40V(200mV-10V), ±2V(2mV-100mV)
Analog Bandwidth	100MHz (DS1102D,DS1102E) 50MHz (DS1052D, DS1052E)
Single-shot Bandwidth	80MHz (DS1102D, DS1102E) 50MHz (DS1052D, DS1052E)
Selectable Analog Bandwidth Limit (typical)	20MHz
Lower Frequency Limit (AC –3dB)	≤5Hz (at input BNC CONNECTOR)
Rise Time at BNC, typical	<3.5ns, <7ns, On (100M, 50M) respectively
DC Gain Accuracy	2mV/div-5mV/div: ±4% (Sample or Average acquisition mode) 10mV/div-10V/div: ±3% (Sample or Average acquisition mode)
DC Measurement Accuracy, Average Acquisition Mode	Average of ≥16 Waveforms with vertical position at zero: ±(DC Gain Accuracy×reading+0.1div+1mV) Average of ≥16 Waveforms with vertical position not at zero: ±[DC Gain Accuracy×(reading+vertical position)+(1% of vertical position) + 0.2div] Add 2mV for settings from 2mV/div to 200 mV/div
	Add 50mV for settings from >200mV/div to 10V/div
Delta Volts Measurement Accuracy (Average Acquisition Mode)	Delta Volts between any two averages of 16 waveforms acquired under same setup and ambient conditions: ±(DC Gain Accuracy×reading + 0.05 div)

Trigger		
Trigger Sensitivity	0.1div~1.0div (adjustable)	
Trigger Level Range	Internal	±5 divisions from center of screen
	EXT	±1.2V
Trigger Level Accuracy (typical) applicable for the signal of rising and falling time ≥20ns	Internal	±(0.3div × V/div)(±4 divisions from center of screen)
	EXT	±(6% of setting + 200 mV)
Trigger Offset	Normal mode: pre-trigger (262144/ sampling rate), delayed trigger 1s	
	Slow Scan mode: pre-trigger 6div, delayed trigger 6div	
Trigger Holdoff range	100ns~1.5s	
Set Level to 50% (Typical)	Input signal frequency ≥50Hz	
Edge Trigger		
Edge trigger slope	Rising, Falling, Rising + Falling	
Pulse Trigger		
Trigger condition	(>, <, =) Positive pulse, (>, <, =) negative pulse	
Pulse Width range	20ns ~10s	
Video Trigger		
Video standard & line frequency	Support standard NTSC, PAL and SECAM broadcast systems. Line number range: 1~525 (NTSC) and 1~625 (PAL/SECAM)	
Slope Trigger		
Trigger condition	(>, <, =) Positive slope, (>, <, =) negative slope	
Time setting	20ns~10s	
Alternate Trigger		
Trigger on CH1	Edge, Pulse, Video, Slope	
Trigger on CH2	Edge, Pulse, Video, Slope	
Pattern Trigger[1]		

Trigger mode	D0~D15 select H, L, X, ,
Duration Trigger[1]	
Trigger Type	D0~D15 select H, L, X
Qualifier	>, <, =
Time setup	20ns~10s

Measurements		
Cursor	Manual	Voltage difference between cursors (ΔV) Time difference between cursors (ΔT) Reciprocal of ΔT in Hertz (1/ΔT)
	Track	Voltage value for Y-axis waveform Time value for X-axis waveform
	Auto	Cursors are visible for Automatic Measurement
Auto Measure		Vpp, Vamp, Vmax, Vmin, Vtop, Vbase, Vavg, Vrms, Overshoot, Preshoot, Freq, Period, Rise Time, Fall Time, +Width, -Width, +Duty, -Duty, Delay1→2, Delay1→2

[1] For DS1000D Series; [2] When sampling is 1GSa/s, only single channel can be used.

General Specifications

Display	
Display Type	5.7 in. (145 mm) diagonal TFT Liquid Crystal Display
Display Resolution	320 horizontal ×RGB×234 vertical pixels
Display Colour	64K colours
Display Contrast (typical)	150:1
Backlight Brightness (typical)	300 nit Nit is a a unit of luminance equivalent to one candela per square metre (1 cd/m²)

Probe Compensator Output	
Output Voltage(typical)	Amplitude ~3Vp-p
Frequency(typical)	1kHz

Power	
Supply Voltage	100 ~ 240 VACRMS, 45~440Hz, CAT II
Power Consumption	Less than 50W
Fuse	2A, T rating, 250 V

Environmental	
Ambient Temperature	Operating 10℃～ 40℃
	Non-operating -20℃～ +60℃
Cooling Method	Fan force air flow
Humidity	+35℃ or below: ≤90% relative humidity
	+35℃～ +40℃: ≤60% relative humidity
Altitude	Operating 3,000 m or below
	Non-operating 15,000 m or below

Mechanical		
Size	Width	303mm
	Height	154mm
	Depth	133 mm
Heavy	Without package	2.4 kg
	Packaged	3.8 kg

IP Degree
IP2X

Calibration Interval
The recommended calibration interval is one year

FINAL REMARKS

See manual for Rigol DS1052 - DS1000D-DS1000E Manual.pdf

LITERATURE AND OTHER RECOMMENDED MATERIAL

1. Joseph McGhee, Wlodek Kulesza, M. Jerzy Korczyński, I. A. Henederson, Scientific Metrology, Published by Technical University of Lodz, printed by: ACGM LODART S. A. Łódź, 1998, ISBN 83-904299-9-**3,**
2. DS1000D-DS1000E Manual.pdf
   http://www.rigolusa.com/support/usermanuals.html
3. Rydzewski J.: Pomiary oscyloskopowe, WNT, Warszawa 1994
4. Stabrowski M.: Miernictwo Elektroniczne, Cyfrowa Technika Pomiarowa, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 1999
5. Dusza J., Gortat G., Leśniewski A.: Podstawy miernictwa, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 1998
6. Tumański S.: Technika pomiarowa, WNT, Warszawa 2007

Additional information:

WWW of instruments description :

www.agilent.com

www.tektronix.com

www.lecroy.com

Lodz University of Technology
INTERNATIONAL FACULTY OF ENGINEERING
Department of Semiconductor and Optoelectronics Devices; **WWW.DSOD.PL**
http://www.ife.p.lodz.pl/downloads/Korczynsk
marian.korczynski@p.lodz.pl

LABORATORY OF MEASUREMENTS

EXPERIMENT NO:	**2**
EXPERIMENT TITLE:	**Digital Oscilloscope used for engineering measurements**

LABORATORY GROUP		***Program/Term***	
No.	***STUDENT'S NAME***		***ID***
1			
2			
3			
4			

Lecturer:	
Data date of experiment:	
Data of submitted report :	
Mark:	
Comments	