Operation Manual of

Piezo-Acquisition System

PAQ-16000D

EN

EC ELECTRONICS

TABLE OF CONTENTS

LIST OF FIGURES

I. BASIC INFORMATION

1. Destination

The PAQ-16000D device is the second version of the system for generation and acquisition of lamba and resilient waves. It was designed as a tool for research of the state of the structure of thin plates with the use of lamba packages and receipt of the response signals from the object. Whole investigation is realised by piezoelements. On the basis of the plate's reaction it is possible to detect both external and internal defects of the object. After the experiment the data of excitation and response signals are sent to PC via the USB, where these signals may be displayed and analysed with the use of software working in MatLab® environment. The device is also equipped with BNC connectors which allow to fast visualisation of the experiment on the oscilloscope.

2. Parameters

PAQ-16000D has the following parameters:

- ➔ general features:
  - power supply.....115/230 VAC, 60/50 Hz
  - communication interface.....USB
  - software environment.....MatLab®
  - piezoelements.....CMAR03, up to 16 pieces, mountable without influence on the structure
  - dimensions.....rack 19” 3U
  - weight.....4 kg
- ➔ operational parameters:
  - number of excitation/measuring channels (total).....1/15 (16) or 1/7 (8)
  - regulation of excitation signal amplitude (gain).....1, ½, ¼, ⅛
  - frequency of lamba package.....30-350 kHz
  - number of periods in package.....1-16
  - lamba waves modulation.....Hanning, triangular, rectangular window
  - delay between generated packages.....1-4095 ms
  - amplifier voltage output.....±100 V
  - regulation of response signal amplitude (gain).....1, ½, ¼, ⅛, 1/10, 1/20, 1/40, 1/80
  - sampling frequency of measuring channels.....2,5 MHz
  - analogue-digital converter.....24 bit

3. Installation

PAQ-16000D device is mounted in the standard 19” rack with height of 3U. On the front panel are placed following elements: input and output ports of 16 channels, display, diodes visualising the state of the unit. The back panel has the power supply port, operational voltage switch, USB port and openings for fans. Installing the device inside a 19” rack cabinet one must provide convenient access to the front panel (for easy plug-in and plug-out of piezoelements) and rear panel (for easy connection of power supply and USB cable and to allow the free air flow).

II. MECHANICAL DESCRIPTION

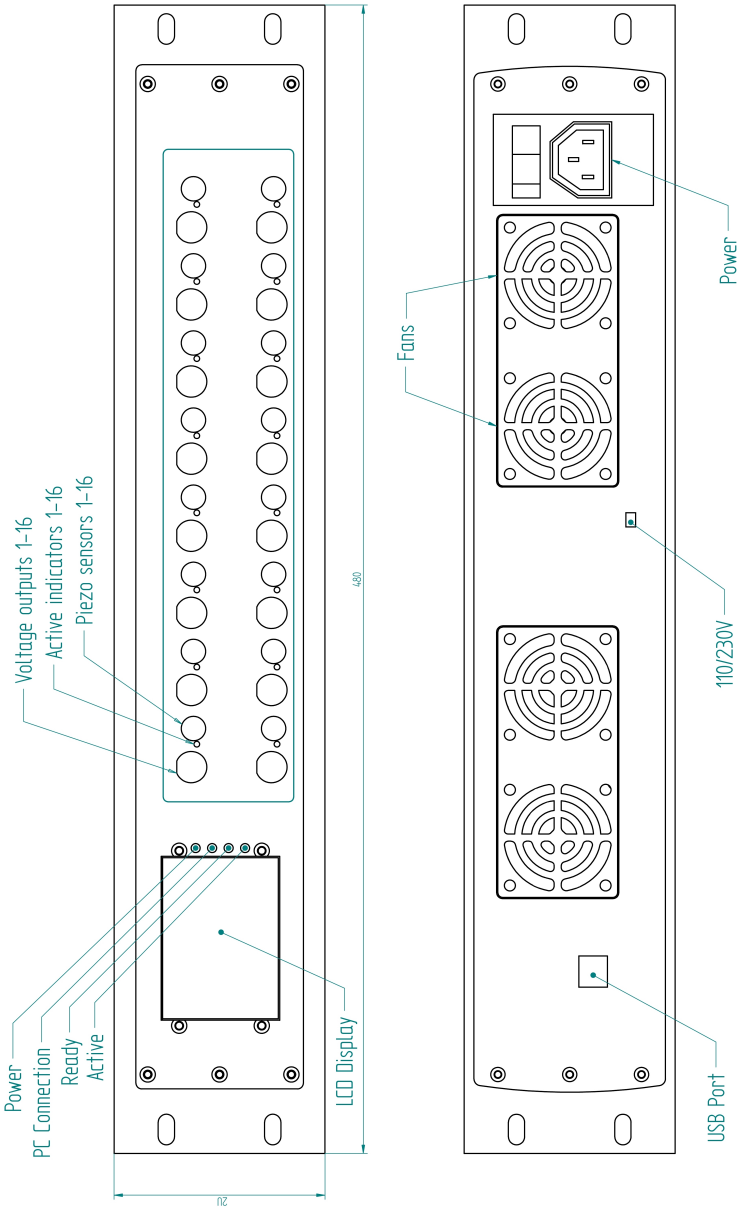

Figure 1: Front and rear panels of PAQ-16000D

1. Front panel

Description of the front panel:

- ➔ LCD display – displaying current configuration and operational parameters,
- ➔ Power, PC connection, Ready, Active – diodes for visualisation of the device's state,
- ➔ Voltage output – charge amplifier output; for each channel,
- ➔ Piezo sensor – port for piezoelement plug-in; for each channel,
- ➔ Active indicator – activation state of the piezogenerator – the diode is shining while sending the lamba package of the excitation signal; for each channel.

2. Rear panel

Description of the rear panel:

- ➔ USB port – port for connection with a PC,
- ➔ 110/230V – switch of the supplying voltage,
- ➔ Power – power supply port with 1A fuse under the socket,
- ➔ Fans.

III. ELECTRICAL DESCRIPTION

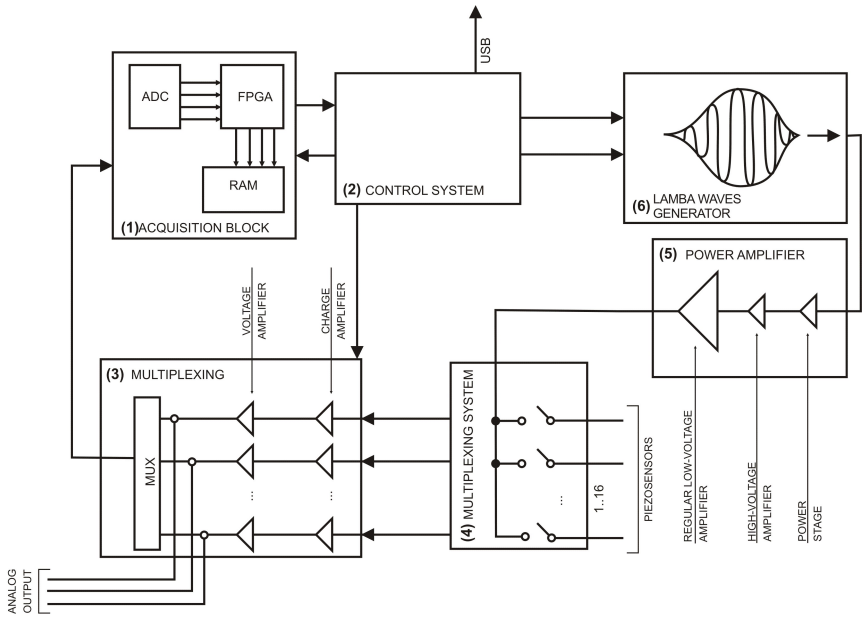

Figure 2: Scheme of the device

The device is based on two integrated circuits – FPGA unit (1) and microprocessor (2). Additionally, PAQ-16000D is equipped with sophisticated parts providing proper operation – package generator in the form of envelope generator (6), frequency generator and multiplier. The feedback measuring channel possess charge and voltage amplifier and analogue-to-digital converter (3).

Communication with the instrument is held by USB interface and MatLab® environment. The USB protocol service is implemented in the FPGA unit. Due to the amount of sampled data during the measurement procedure it is not possible to send them to the PC directly. That is why the FPGA unit firstly stores the measurement data in the RAM memory. After completing the acquisition period all data are sent to the MatLab® via the USB port.

PAQ-16000D has the possibility of excitation and response signals power regulation. It is necessary due to specific parameters of tested objects – different materials have different wave propagation features.

Analogue-to-digital sampling is done with the 24 bit resolution and 2,5 MHz frequency. Such features of measurement requires properly designed power supply. Due to this demand the process is powered by the internal battery. The converter has an anti-aliasing filter implemented. After the conversion the signal is digitally filtered or damped by chosen gain.

For the measuring purposes bandwidth of the measuring channel was limited to the range 10-350 kHz.

The FPGA unit and microcontroller, beside duties connected with measuring experiments, handle the parameters of the PAQ-16000D device.

IV. OPERATION WITH THE PAQ DEVICE

The order of steps and their description while using the device is as following:

1. Connection to the PC

Data exchange between PAQ-16000D and the PC is held by the USB interface. For a proper operation it is recommended to connect the devices before starting the computer:

- ➔ connection of the devices with the use of USB cable,
- ➔ installation of FPGA drivers – only at the first start-up (PAQ-16000D should be turned on during this process for proper unit identification),
- ➔ starting the program for using PAQ-16000D – type *„paq”* in MatLab® command window,
- ➔ menu → Configure → Connect to device – proceed always after starting the program,
- ➔ menu → Configure → Select Bit File – choice of the program for the FPGA unit,
- ➔ menu → Configure → Load Bit File – loading the program to the FPGA unit.

In the case whet the bit file is present in the current operational directory of MatLab® it is enough to proceed directly to the Load Bit File procedure.

After execution of precedent operations the device is ready for work.

2. Connection of piezoelements

The measuring set consists of 16/8 piezoelements (at most) with soldered supplying cable terminated with the SMA connector. To run the experiment one must at first connect required number of piezoelements to the SMA connectors on the front panel and glue them to the investigated structure with the use of wax, kapton or special glue for piezoelements.

3. Launching

Before starting the device it is necessary to set the supply voltage switch on the rear panel to the proper position – 115 or 230 VAC!

PAQ16000-D should be turned when the PC is already working. This will help in proper recognition and communication between computer and device.

4. Channel configuration, measurement and data acquisition

Operations concerning setting up and exploitation of PAQ-16000D are described in details in the following main chapter V – "Channel configuration, measurement and data acquisition".

5. Finalising the work

Turning down PAQ-16000D should be performed when the device is idle. The power supply is disconnected when the position power switch is changed from "ON" to "OFF". Later stating-up of device is possible without restarting of the computer.

V. CHANNEL CONFIGURATION, MEASUREMENT AND DATA ACQUISITION

1. Program

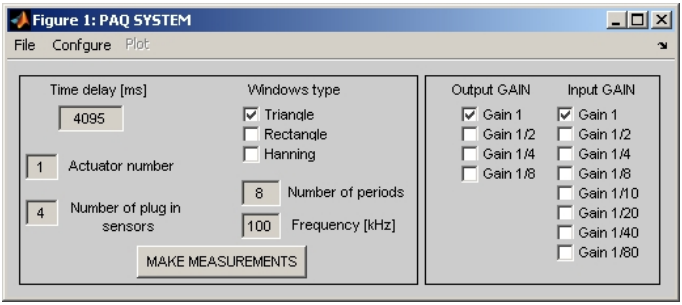

Figure 3: Operational window of the PAQ-16000D software

Menu of the program:

- ➔ File:
  - Save as – storing the last session of experiments in a paq_data.mat file,
  - Exit – closing the program,
- ➔ Configure:
  - Connect to device – connection with PAQ16000D,
  - Select bit file – choosing the program managing the experimental parameters of the device,
  - Load bit file – loading the program managing the experimental parameters to the device,
- ➔ Plot – graphical representation of the results of a experiment.

Parameters of the program:

- ➔ Time delay – time in [ms], after which the packages for consecutive piezoelements are generated,
- ➔ Actuator number – number of a piezoelement which is going to be the exciter – generator of the lamba excitation signal,
- ➔ Number of plug in sensors – total number of all piezoelements connected to PAQ-16000D taking part in an experiment – exciter + sensors,
- ➔ Windows type – modulation window type for the generated excitation package,
- ➔ Number of periods – number of periods composing the excitation signal,
- ➔ Frequency – frequency in [kHz] of the excitation signal,
- ➔ Output gain – amplification (in reality the damping factor) of the generated excitation signal,
- ➔ Input gain – amplification (in reality the damping factor) of the measuring signals.

Having set-up the parameters to start the experiment one has to choose the button „Make Measurements". After collection of the data they may be presented graphically.

2. Structure of the data

The experimental session is temporarily stored in the workspace of MatLab® in the "paq_current_data" structure. The structure contains records of consecutive experiments with their pre-set parameters and measured response data. While the program is restarted, the old session is deleted and a new one is created.

3. Exemplary set-up of parameters and results of experiment

Exemplary experiment was performed on the copper plate with dimensions 48x100x0,1 cm. The test rig and distribution of piezoelements on the object is presented on the following figures:

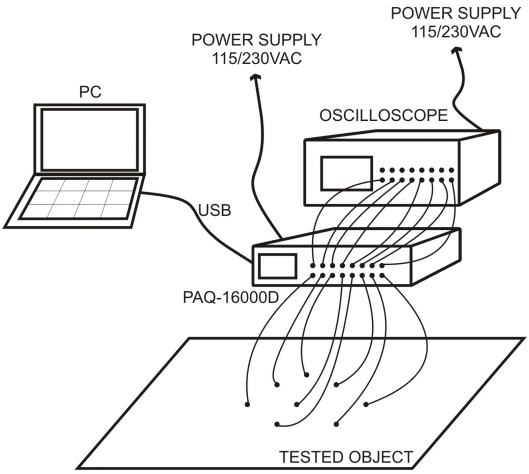

Figure 4: Exemplary test rig

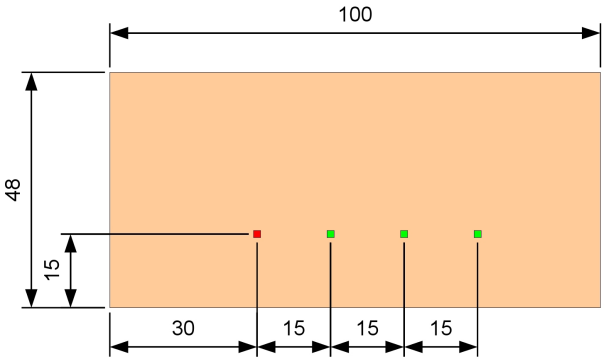

Figure 5: Arrangement of the piezoelements on the structure

Red-coloured element was the exciter of the lamba package.

Parameters of the experiment were chosen as follows:

- ➔ Actuator number – 1,
- ➔ Number of plug in sensors – 4,
- ➔ Window type – Hanning,
- ➔ Number of periods – 10
- ➔ Frequency – 200 kHz,
- ➔ Output gain – 1,
- ➔ Input gain – 1.

The generated lamba package sent to the tested object as the exciting signal had the shape:

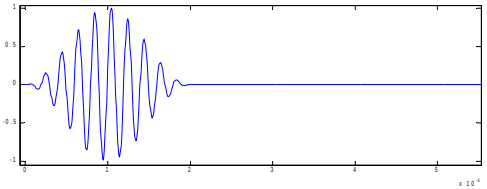

Figure 6: Exciting lamba package - 10 periods, 200 kHz, Hanning window

Performed experiment gave the piezoelement time responses presented on the following figure:

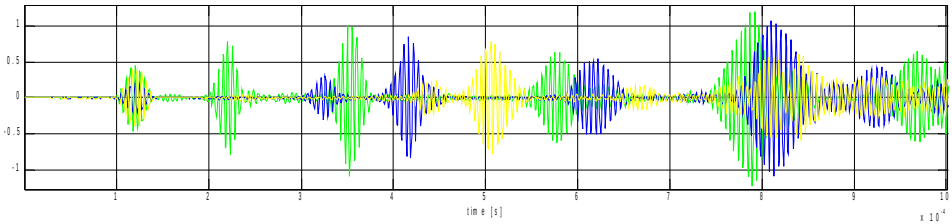

Figure 7: Time responses of the piezosensors

Results from the experiment show the excitation signal (from the cross-talk, at the time 1,2 ms) and then the time response measured by the consecutive piezoelements. There is clearly seen that the sensors were placed in increasing distance from the exciter. Succeeding (after 7 ms) measured vibrations were the one reflected from the boundaries of the plate. Knowing the parameters of the excitation, material and dimensions of the investigated structure one can check, whether measured response comes from the boundary or from some crack (external or internal). One has to remember, that due to the echo and interference of mechanical waves, the most significant are the first measured responses.

Generation of the resilient waves in the form of packages is connected with several phenomena taking place in the real object. For proper analysis of the non-homogeneous objects the most concentrated bandwidth of the excitation is required. In other case the time differences in the speed of propagation of longitudinal and transverse waves occurs.

For more detailed research of the results of the experiment it is recommended to make the analysis of the response in the frequency domain.

VI. SAFETY

WARNING! The device is powered by high voltage source. There is the must to check the proper supplying voltage – switch on the rear panel.

WARNING! The device generates the high voltage impulse outputs – one has to pay the attention during the operation of the device.

WARNING! During distribution of piezoelements on the metal plates one cannot short circuit the supplying wires of piezoelement with the tested object.

VII. CONTENT OF THE PAQ-16000D SET

The PAQ-16000D set includes:

- ➔ unit for generation and acquisition of the resilient waves – PAQ-16000D,
- ➔ set of piezoelements,
- ➔ drivers for FPGA unit,
- ➔ software in the form of MatLab® m-files,
- ➔ operation manual,
- ➔ cable for power supply,
- ➔ USB cable.