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INSTRUCTION HANDBOOK FOR THE MELLES GRIOT NANOPOSITIONING MODULAR SYSTEM

PIEZOELECTRIC CONTROL MODULE

COVERING PRODUCTS OF NUMBER 17MPZ001

MELLES GRIOT

Cambridge
England

MG Ltd part number HA0087 issue 3

Revision History

The following table shows the revision history of this handbook:

Issue Number	Date	Summary of amendments
1	10-Jul-98	
2	25-Sep-98	C/N 2229
3	22-Mar-99	C/N 2308

Safety Information

Read this information carefully before installing or using the equipment.

This unit complies with the European Standard EN61010 as a POLLUTION DEGREE I, INSTALLATION CATEGORY II piece of equipment.

The Equipment, as described herein, is designed for use by personnel properly trained in the use and handling of mains powered electrical equipment. Only personnel trained in the servicing and maintenance of this equipment should remove its covers or attempt any repairs or adjustments.

For the continuing safety of the operators of this equipment and the protection of the equipment itself the operator should take note of the **CAUTIONS** and **WARNINGS** throughout this handbook and, where visible, on the product itself.

The **CAUTION** statement is used to alert the user to the correct method of operating the equipment without injury or damage being caused.

The **WARNING** statement alerts the user to areas of the product that may be hazardous to health.

Safety symbols

The following safety symbols may be used on the equipment:



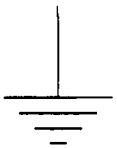
Read the operating instructions before use



Connection to earth



High voltages present



EARTH point

Identifying unsafe equipment

Whenever it is suspected that the safety of the product has been impaired, it is recommended that an appropriate label, recognised by your company, be attached and that the unit be removed to a place of repair.

Electrical connections

The module should be connected to no electrical equipment, other than the purpose made rack. Use the module to drive only Melles Griot piezoelectric stages and actuators. Never attempt to drive any other type of equipment from the module.

Internal fuses

The following fuses are used on the circuit board of the module. They are not user replaceable.

Fuse	Rating/A	Type
F1	0.75	T Nanofuse, antisurge
F2	0.75	T Nanofuse, antisurge
F3	0.5	T Nanofuse, antisurge
F4	0.5	T Nanofuse, antisurge
F5	1	T Nanofuse, antisurge

Environmental conditions

The unit has been designed to operate normally under the following environmental conditions:

Location	Indoor use only
Maximum altitude	2000 m
Temperature range	5°C to 40°C
Maximum humidity	Less than 75%

CAUTION→ **CARE SHOULD BE TAKEN TO ENSURE THAT PROPER AIRFLOW TO THE UNIT IS MAINTAINED.**

WARNING→ **OPERATION OUTSIDE THE ABOVE LIMITS MAY ADVERSELY AFFECT OPERATOR SAFETY.**

Output voltage

The Drive Output is rated as follows:

Nominal maximum	75 V
Absolute maximum	100 V

WARNING→ **THE DRIVE OUTPUT VOLTAGE POSES A POTENTIAL SAFETY HAZARD.**

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How to use this handbook

Before using the equipment, please read carefully the Safety Information on page i.

The handbook begins with a description of the module including its front panel controls and indicators. It explains the principles of nanopositioning using piezoelectric actuators. It describes operation from the front panel, and then goes on to explain the more advanced features accessible through programmed operation from the Controller.

To use the Piezoelectric Control module, you need a Main Rack, a Controller, a piezo-actuated stage and software drivers for the language you are using. Please refer to the instruction handbooks for these complementary products, as tabulated below.

In particular, the handbook for the *Main Rack and Controller* covers how to install the module into the rack and how to configure the whole system from software using the configuration program MG17_Config.

Table 1: Complementary products and instruction handbooks for the Melles Griot Nanopositioning modular control system. Note that new products may be added to this list.

Product Name	**Product Number(s)**	**Part number of Instruction Handbook**
Main rack and controller	17MMR001 17MRC001 17MRC002	HA0088
NanoStep Motor Control Module	17MST001	HA0085
Piezoelectric Control Module	17MPZ001	HA0087
NanoTrak Control Module	17MNA001	HA0086
LabVIEW drivers	17LVD002	HA0091
Visual Basic drivers	17VBD002	HA0092
Dynamic Link Libraries		HA0093
NanoMax-HS 6 axis stage	17MAX600 series	HA0083
NanoMax-HS 3 axis stage	17MAX300 series	HA0094
NanoStep Linear stages	17NST101 series	HA0031
NanoRotator	17AMR101	HA0040

Technical Support

If you cannot find the answers you need in these handbooks, please contact us for technical support either through your local representative, or at the address below:

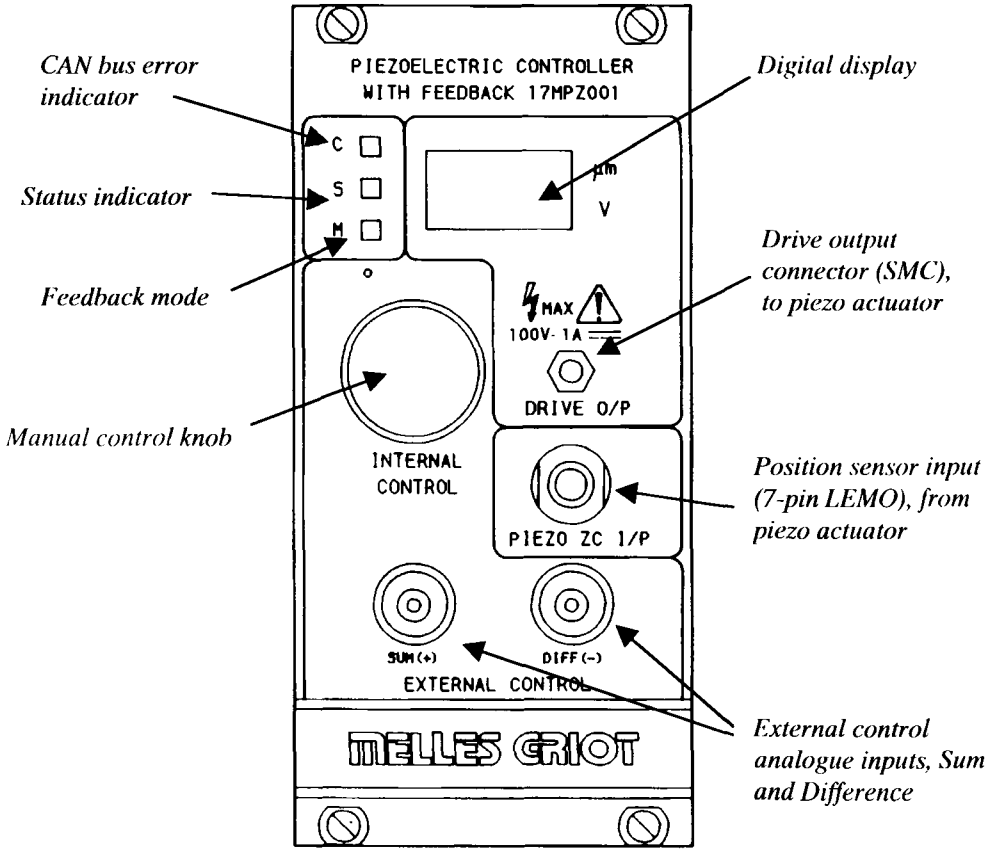
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St Thomas Place
Cambridgeshire Business Park
Ely
Cambridge CB7 4EX, UK
Telephone: +44 (0) 1353 654500
Fax: +44 (0) 1353 654555

It is always helpful to have detailed and accurate information about any problem you encounter.

We welcome your comments or suggestions about any aspect of the equipment and instruction handbooks.

Description of front panel

The design of the Piezoelectric Control module is such that basic operation may be carried out from the front panel, whereas more advanced operation is possible from the Controller through software.



CAN bus error indicator shows an error in communication between the module and the Controller. A yellow light shows that the module can listen but not talk to the Controller. A red light shows that it can neither listen nor talk. When the light is off, there is no error.

Status indicator A green light shows that the Controller is addressing the module. A red light warns of overheating.

Feedback mode indicator shows closed-loop control when illuminated, open-loop control when not illuminated. A flashing light shows that closed-loop mode is selected but no signal is available from the sensor.

Manual (internal) control knob used to set the voltage or position of the piezo actuator.

External control analogue inputs are used to control the position from an external analogue source, for example the NanoTrak controller. The output of the module is proportional to the Sum (+) input minus the Difference (-) input.

Position sensor receives the signal from the position sensor of the piezo actuator as required by the feedback control loop.

Drive output provides the connection to the piezo actuator, carrying a maximum of 100 V.

Digital display (3 digit) shows the voltage or position (in microns) of the actuator.

Principles of Piezoelectric Nanopositioning

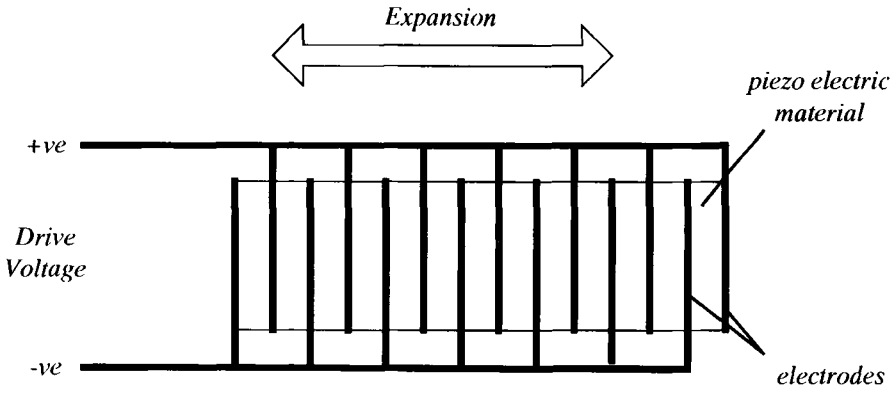
The piezoelectric effect

Piezoelectricity is the effect whereby certain types of crystal expand reversibly when subject to an electric field.

Although the amount of expansion is usually very small (corresponding to less than 1% strain in the material) it can be controlled extremely finely by varying the strength of the electric field. Piezoelectric materials therefore form the basis of very high precision actuators. The resolution of these actuators is effectively only limited by the noise and stability of the drive electronics. Further, the force generated by the expanding piezo is very large, typically hundreds of newtons.

Perhaps the most useful property of these actuators is their ability to produce oscillating motion at considerable frequencies, usually limited by the mechanical system driven rather than by the piezo actuator itself. This ability is used to advantage in the NanoTrak control system, for example.

The electric field gradient needed to produce a useful amount of expansion is quite large. Thus to avoid excessive drive voltages, the actuator is constructed as a stack, consisting of lamina of active material sandwiched among electrodes. In this way, the distance from positive to negative electrodes is very small. A large field gradient can therefore be obtained with a modest drive voltage of 75 V in the case of Melles Griot actuators.

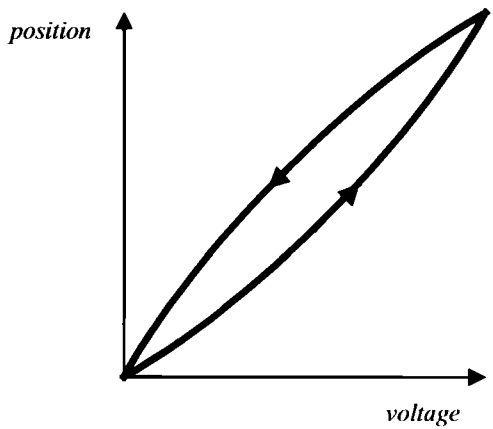


Hysteresis

Despite the very high resolution of piezoelectric actuators, a drawback important in some applications is the significant amount of hysteresis.

Hysteresis means the tendency of the actuator to reach a final position that lags behind the demand position.

If a cyclic voltage is applied to the actuator and the position is plotted against voltage, the positions reached on the upward sweep of the graph are smaller than those achieved on the downward sweep. The graph describes a hysteresis loop, as shown below.



Position sensing and feedback control

Hysteresis can be eliminated by a sensor and feedback loop.

The sensor measures the position. The circuit subtracts the measured position from the demand position to get the error. A proportional-integral feedback loop adjusts the voltage to the actuator until the error is virtually zero.

Some Melles Griot nanopositioning actuators have position sensing, others do not. The Piezoelectric Control module allows both types to be controlled.

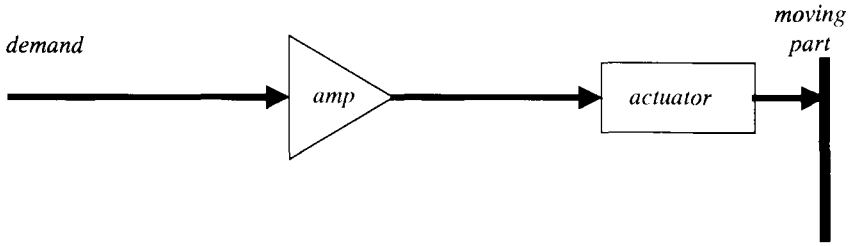
To control an actuator *with* position sensing, the Piezoelectric Control module is switched to *closed-loop* mode.

To control an actuator *without* position sensing, the Piezoelectric Control module is switched to *open-loop* mode.

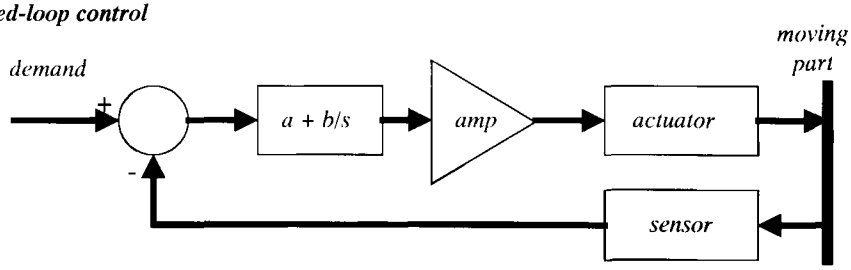
Note that an actuator *with* position sensing can also be driven in *open-loop* mode if desired, since the feedback part of the circuit can be switched off. An advantage of open-loop mode is the greater bandwidth of the system.

Block diagrams for the two modes of operation are shown below:

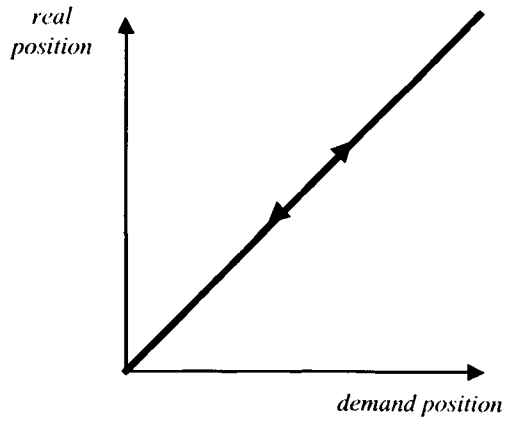
Open-loop control



Closed-loop control



The result of using the closed-loop is a linear relation between demand and measured position, in contrast to the graph on page 7.



Setting the zero of the position sensor

When the actuator is at zero position, the position sensor gives a small signal called the offset. Such an offset enables the sensor to measure small negative movements i.e. contractions of the piezo.

The offset differs slightly from one actuator to another. Therefore, when an actuator is connected to the module it is necessary to adjust for the new offset. This is done using controls implemented on the Controller PC.

Choice of display mode

It is possible to set the module to display either the voltage applied to the actuator or the position measured by the sensor (in microns). Even if the module is in open-loop mode, the signal from the position sensor can still be displayed.

In the case of actuators with position feedback, there are therefore 4 modes of operation in total

1. Open-loop, display voltage applied to actuator
2. Closed-loop, display position (microns) measured by sensor
3. Closed-loop, display voltage applied to actuator
4. Open-loop, display position (microns) measured by sensor

Note that these options can be selected through software, but from the front panel of the module. On power up, the module defaults to the first mode above.

Detection of range of travel

In the case of actuators with position sensing built in, the Piezoelectric Control module can detect the range of travel of the actuator since this information is programmed in the electronic circuit inside the actuator.

Through software, it is possible to get the range of travel of the actuator.

This feature is not present in actuators without position sensing.

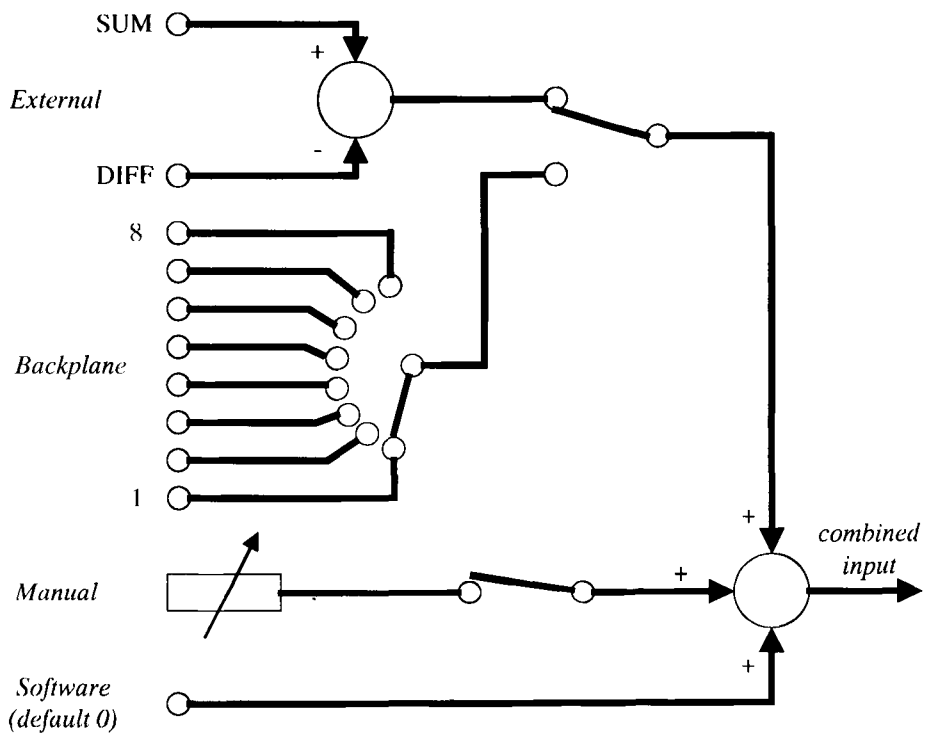
Selection of input source

The input source provides a means of controlling the position of the actuator from an analogue signal.

Analogue connections among modules can be made with external, BNC-terminated cables. Alternatively, it is possible to route signals connecting the modules along any of 8 lines on the backplane of the rack.

Sources can be summed. The various options available regarding the selection of input source are explained in the diagram below. These options can be selected through software, but not via the front panel of the unit.

On power up, the default option is as shown in the diagram.

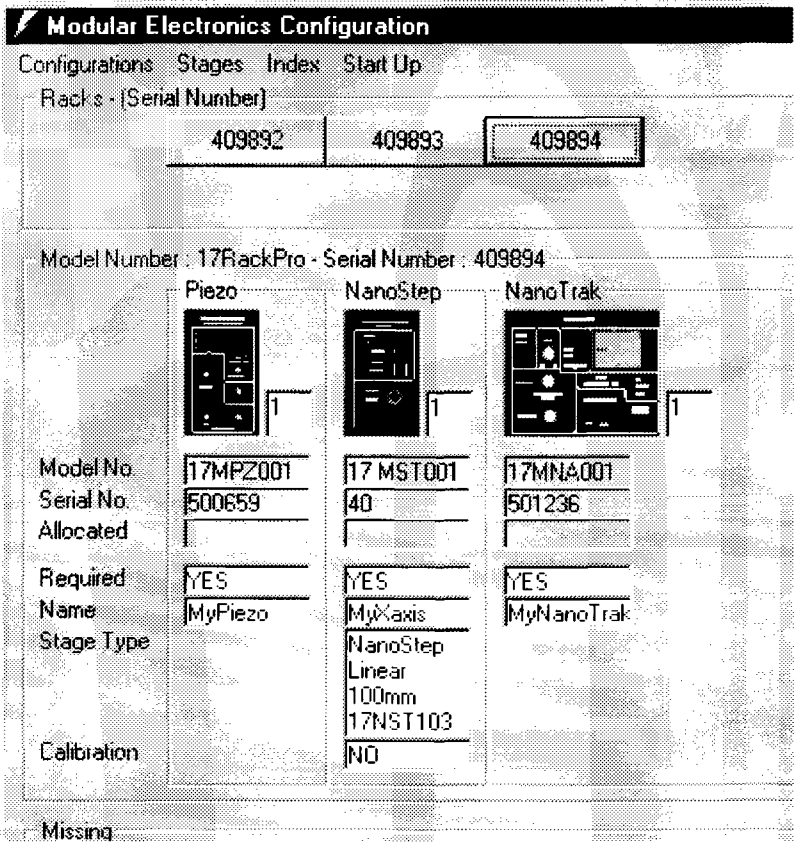


Connecting an actuator to the module

Before connecting an actuator or stage to the module, turn the manual control knob on the front panel anti-clockwise to zero. Connect the Drive output first (small, SMC connector) then, if used, the position sensor (larger, 7-pin LEMO connector), making sure the two connections are from the same axis of the stage.

Configuring the Controller

The configuration program MG17_Config (illustrated below) enables you to give a name to the module that can later be used as a handle in programming. See the instruction handbook for the *Main Rack and Controller* for a general description of MG17_Config.



To create a configuration for the Piezoelectric Control module:

Step 1. Run MG17_Config, to be found in the folder MellesGriot\MelHost\Config, or access from the Start\Modular Electronics Host menu.

Step 2. Click (left-hand mouse button) on the icon of the module your stage is connected to. The green STATUS light on the panel of the module flashes once as an aid to identification.

Step 3. If desired, drag the module icon into the slot on the screen that corresponds to the position of the real module in the real rack (this will make it easier to identify the module).

Step 4. Click (left-hand mouse button) on the Required field for the module. Select YES if you want to use this module.

Step 5. In the Name field, type a meaningful name of your choice. Later, you will use this name as a handle to the module when programming.

Step 6. Repeat 2 to 5 for each module you wish to configure.

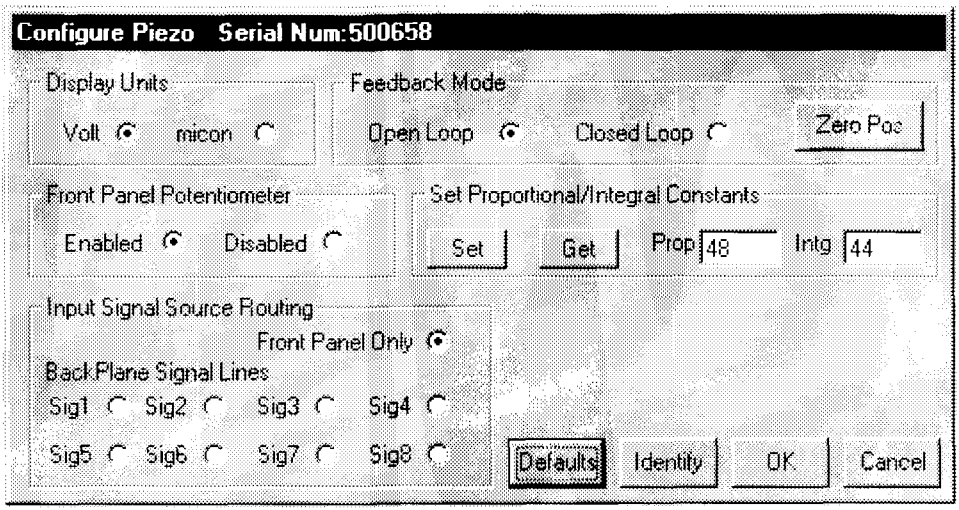
Step 7. From the Configurations menu (top left-hand corner of screen), save the configuration you have created using a meaningful name of your choice. You may use this name later in the initialization part of a program you create.

Note that the Stage Type field is not used in the case of this module.

Configuring the Piezo

Right-click on the Piezo icon to access the Configure Piezo Window (see below). This window allows you to set parameters relating to the Piezo:

- Set the display to volts or microns
- Set the feedback mode to open or closed loop
- Zero the sensor: this is recommended before you use the piezo in closed-loop mode
- Set parameters for the feedback control loop. This affects the settling time and stability of the loop. Use the defaults button to restore the defaults.
- Set backplane signal lines. This allows the module to be connected to a NanoTrak without external cables.



Operation from the front panel

Adjusting the position

Once the actuator is connected to the module, you can adjust the position of the actuator (or stage) using the 10-turn potentiometer on the front panel. Use the Configure Piezo Window (see above) to switch between open and closed-loop mode. In closed-loop mode, you will probably want to set the display to microns.

Using the external inputs

In open loop mode, the drive output voltage will be:

7.5 x (SUM input voltage – DIFF input voltage)

In closed loop mode, the position will be:

Full actuator extension x (SUM input voltage – DIFF input voltage)/10

Other inputs may be combined with these external inputs, as shown on page 10.

Programmed operation from the Controller

General approach

Whether you are programming the Piezoelectric Control module in LabVIEW, Visual Basic or another language, the general approach is the same. A typical application contains the following main steps:

Step 1. Load the configuration file and get handles for the axes you wish to control. The handles are used as inputs to subsequent functions. The handles are user-chosen names as defined in MG17_Config (see page 11).

Step 2. Operations such as setting the voltage or setting the position. This step is usually the main body of the application.

Step 3. Release the handles, to let the server know you have finished using them. The axes are then free to be used by another application.

The first and last steps are similar for all types of control module, including the Piezoelectric Control module. More details can be found in the software handbooks (see page 2).

The functions used in ***Step 2*** are now described in more detail:

Functions of the Piezoelectric Control module

The following functions of the Piezoelectric Control Module have been implemented in LabVIEW and Visual Basic. In each language, you will find functions of similar names.

More detailed information on these functions and other lower level functions can be found in the software manuals.

Some of these functions (marked *) can only be used if the actuator is equipped with position sensing.

Set inputs

Enables the analogue input source to be a combination of external control inputs, backplane inputs, manual control on front panel and software setting. See page 10.

Get position*

Get the current position of the actuator, as read by the position sensor, in microns.

Get stage travel*

Get the travel of the actuator in microns.

Get voltage

Get the voltage currently applied to the actuator.

Set display

Choose to display position in microns, as read by the position sensor, or to display the voltage applied to the actuator.

Set mode

Choose between closed and open-loop mode.

Set position*

Set the position of the actuator in microns. This function can only be used when in closed-loop mode – otherwise the command is ignored.

Set voltage

Set the voltage applied to the actuator. This function can only be used when in open-loop mode – otherwise the command is ignored.

Zero sensor*

Sets the voltage applied to the actuator to zero and sets the zero of the position feedback sensing. This function is used during initialization.

Specifications

Output voltage:

0-75 VDC (absolute maximum 100 VDC), SMC screw connector
Thermal trip output protection

Output current

0-500 mA peak

Bandwidth

Open loop operation	8.5 kHz
Closed loop operation	500 Hz

Input voltage

0-10 V, BNC connectors, SUM and DIFFerence inputs

Front panel display

3 digit LED

Dimensions	12 HP x 3 U x 220 mm
Weight	1010 g

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