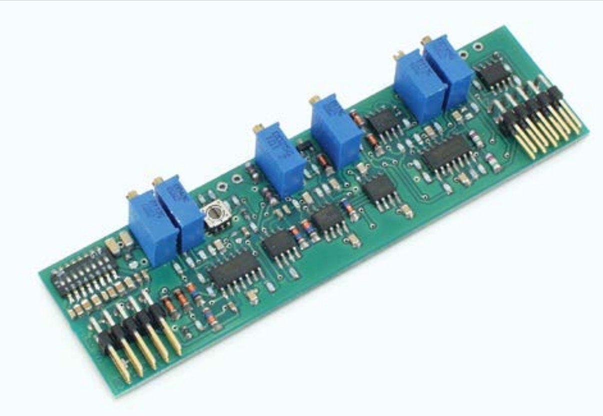
Piezo · Nano · Positioning

PZ 150E User Manual

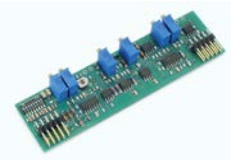
E-802 Servo-Controller Submodule

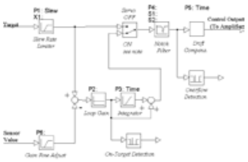
Release: 1.4.0 Date: 2013-11-08



This document describes the following Product(s):

- E-802.55
  Servo-Controller Submodule,
  Revision ADC or higher





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0 Safety Precautions

CAUTION

E-802 submodule boards are ESD-sensitive (electrostatic discharge sensitive) devices. Observe all precautions against static charge buildup before handling these devices.

Avoid touching circuit components, pins and PCB traces. Discharge any static charge you may have on your body by briefly touching a conductive, grounded object before you touch any electronic assembly. Pose PCBs only on conductive surfaces, such as ESD-safe transport containers (envelopes, foam). Electronic subassemblies must always be kept and transported/shipped in conductive packaging.

Make sure that no conductive particles of any kind (metallic dust or shavings, broken pencil leads, loose screws) get on the card.

CAUTION

Calibration of the controller the E-802 is a part of is done prior to delivery by the manufacturer.

Do not adjust potentiometers unnecessarily. Only the zero point will have to be realigned from time to time to compensate for temperature changes. Further adjustments are not required as long as system components are not replaced or modified.

Any calibration procedures are to be carried out by qualified authorized personnel only.

CAUTION

Some adjustment elements on the main board of the controller and on E-802 submodules are covered with sealing lacquer. Damage to the seal will void the warranty except in consultation with PI.

1 Introduction

The E-802.55 is a small add-on printed circuit board (PCB) that processes the control signal for the power amplifier driving piezoelectric translators. Slew rate limitation, notch filter and servo-control loop are all implemented on the E-802.55.

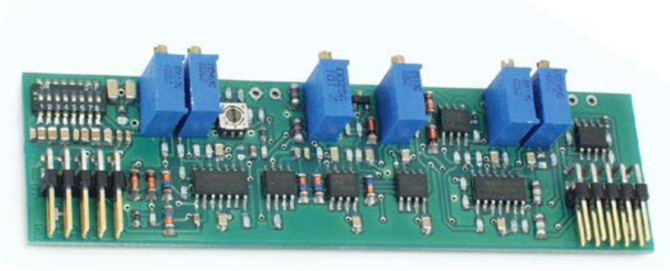


Fig. 1: E-802.55 servo-control submodule

1.1 Functionality

The servo-loop logic compares the control voltage input and the position sensor signal to generate the power amplifier input control signal. An analog proportional-integral (P-I) algorithm is used. Slew rate limitation insures that the output signal slope does not exceed the following capability of the power amplifier. The notch filter is used to damp out oscillation at the resonant frequency of the mechanics.

In summary:

- Slew rate limitation of output signals can be set within the range of 0.1 V/ms up to 1000 V/ms. Note that these values are only valid for the slew-rate-limitation circuit. The values for the complete system are lower due to limitations given by amplifier, notchfilter etc.
- P-I control performance, with individual setting of P- and I-terms.
- Optional notch filter allows suppression of mechanical resonances. The filter frequency and quality can be adjusted by trim potentiometers.
- Servo function can be enabled/disabled via TTL signals (low=servo ON, high=servo OFF).

Excellent long-term stability is accomplished by using exclusively low-tolerance / low-drift components. Residual errors in the range of 0.05% can be compensated with additional trimming components.

The location of the E-802 on the electronics in which it is installed is indicated in the User Manual for that device (e.g. the E-621). This manual describes those functions and procedures specific to the E-802.

1.2 Model Summary

Only the E-802.55, revision ADC or higher is in production, but several earlier, pin-compatible versions may still be in circulation. See the User Manual PZ 113E for information on older versions.

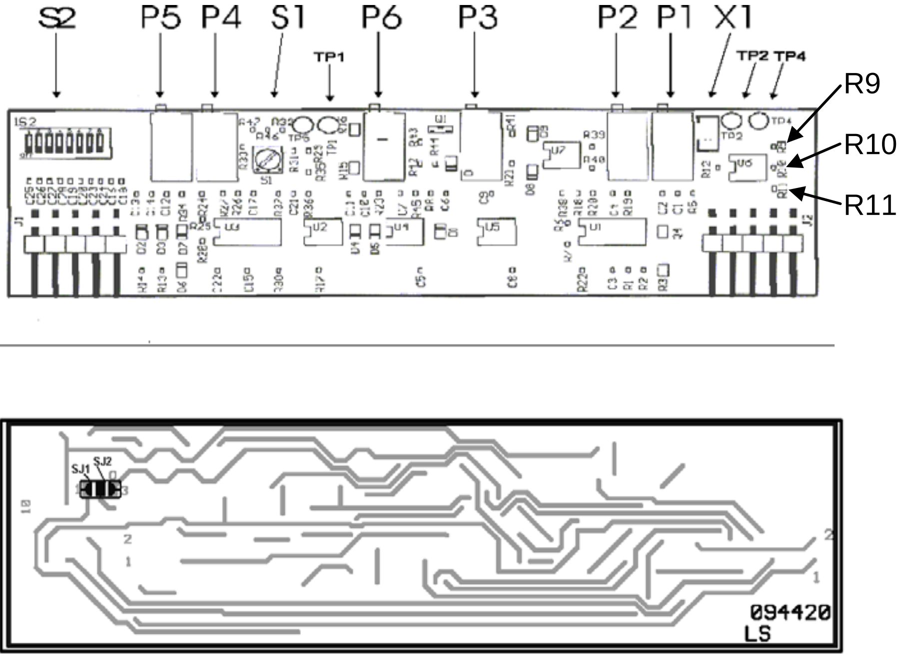
Note that in contrast to earlier versions, E-802.55s leave notch filter and slew rate functions turned on when servo-control is turned off. They also have a mini DIP switch for selection of notch filter frequency ranges, so that component replacement is not necessary.

2 E-802.55 Details

The 802.55 is currently replacing the earlier versions. With the E-802.55 the notch filter and slew rate limiter are also active even when the servo-mode TTL input line is at the servo-OFF level (open-loop operation).

Note: In open-loop mode, the gain may vary by a value in the range of -3% to +6% depending on the setting of P5 (drift compensation potentiometer, see figure below). By default P5 is preset to its mid position.

2.1 E-802.55 Component Locations



Solder bridges SJ1 and SJ2 on back for On Target signal

Fig. 2:

For pinouts see p. 10.

For element description see:

P1 to P6, S1, S2, X1 see below

R9 to R11 on p. 7

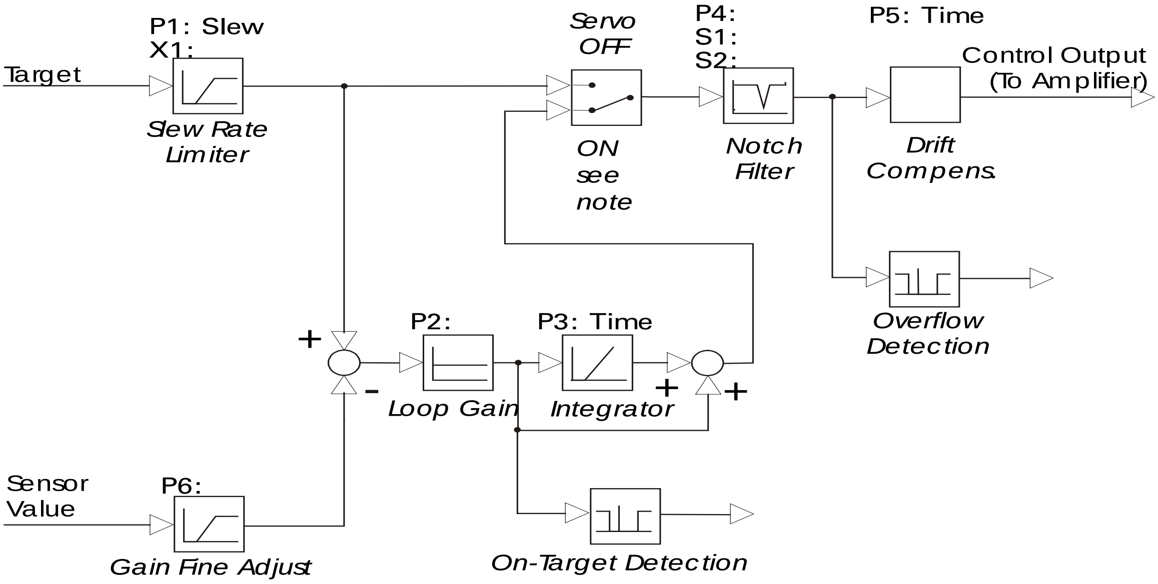
TP1, TP2 and TP4 on p. 8

SJ1 and SJ2, p. 7

2.2 E-802.55 Adjustment Controls

P1	Slew Rate Limitation
P2	Loop Gain (P-Term)
P3	Integration Time Constant (I-Term)
P4	Notch Frequency
P5	Drift Compensation
P6	Sensor Gain Fine Adjust
X1	Slew Rate Range
S1	Notch Filter Damping
S2	Notch Filter Range

2.3 E-802.55 Block Diagram



Note: The servo ON-OFF “switch” is controlled by electrical signals from the board on which the submodule is installed.

Fig. 3: E-802.55 Block diagram

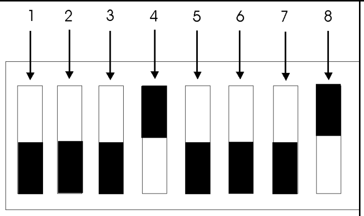
2.4 Notch Filter Settings

2.4.1 Frequency

The notch filter frequency can be set within the currently set frequency range with potentiometer P4 (Fig. 4).

2.4.2 Range

The frequency range is set with the mini DIP switches on block S2 as shown in the table below:

Range No.	Switch Positions 1=ON=up								Min. Frequency	Max. Frequency
	1	2	3	4	5	6	7	8		
1	.	.	.	.	.	.	.	.	2900	9400
2	1	.	.	.	1	.	.	.	940	3100
3	.	1	.	.	.	1	.	.	330	1100
4	1	1	.	.	1	1	.	.	270	900
5	.	.	1	.	.	.	1	.	140	470
6	1	.	1	.	1	.	1	.	130	430
7	.	1	1	.		1	1	.	100	330
8	1	1	1	.	1	1	1	.	94	311
(Example, Range 9)									70	210
9	.	.	.	1	.	.	.	1	70	210
10	.	.	1	1	.	.	1	1	44	148
11	1	1	1	1	1	1	1	1	39	130
12*	1	1	1	1	1	1	1	1	27	89

* Special order with C24+ C28 = 82nF

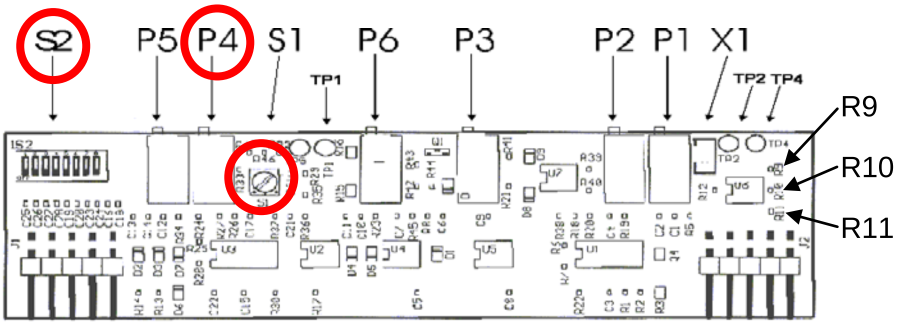


Fig. 4: Locations of S2 *range DIPs*, *P4 frequency and* S1 *damping*

2.4.3 Damping

The damping is set with S1 (use small screwdriver):

S1 Setting (circle):  or  20 dB,  25 dB

2.5 Voltage Ranges and Over-Voltage Recognition

Nominal Voltage Range /V	Actual Voltage Range / V	R9	R10	R11
NV, 0 to100	-30 to +130	2.0 kΩ	16.0 kΩ	12.0 kΩ
HI, -1000 to 0	-1120 to -3	4.02 kΩ	11.3 kΩ	14.7 kΩ
HII, -750 to +250	-790 to +265	12.4 kΩ	10.5 kΩ	7.15 kΩ
HIII, -500 to +500	-560 to +560	9.53 kΩ	11.0 kΩ	9.53 kΩ
HIV, -250 to +750	-265 to +790	7.15 kΩ	10.5 kΩ	12.4 kΩ
HV, 0 to +1000	+3 to +1120	14.7 kΩ	11.3 kΩ	4.02 kΩ

Table 1. E-802.55 component substitution chart for voltage ranges and over-voltage recognition

More precise adjustments are not possible here, as the reference voltage is derived from the operating voltage, which can vary by about 1% from the nominal value. The same tolerance has to be taken into account regarding over-voltage recognition.

2.6 On-Target Detection

The on-target signal is available on J2 pin 2, if SJ2 is closed (see “Solder Bridges” below for details). The on-target signal is TTL active-low, and switches when the distance between the current position and the target is within ±0.19% of the travel range. The width of this tolerance band cannot be adjusted.

2.7 Solder Bridges

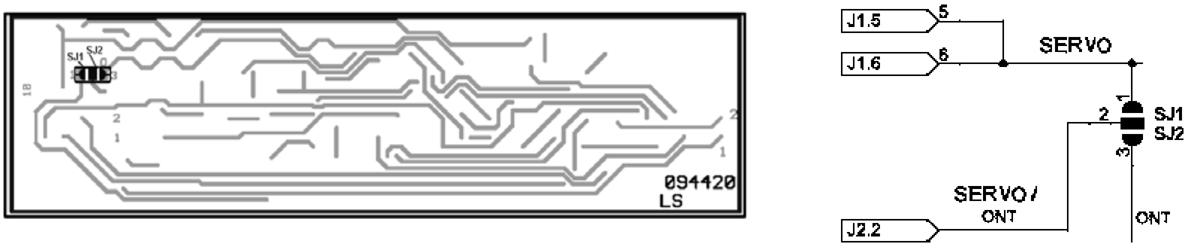


Fig. 5 Solder bridges SJ1 and SJ2

Solder bridges SJ1 and SJ2 on the back of the board will not normally need to be changed. If SJ2 is closed (as when the E-802 is installed in an E-621, E-625 or E-665), then the on-target signal is available on J2 pin 2.

2.8 Test Points

Test point TP1, Slew Rate; Servo ON and OFF (for location see figure on p. 4)

set required rise time using P1, watch PZT voltage and sensor values

Typical curve at positive input step:

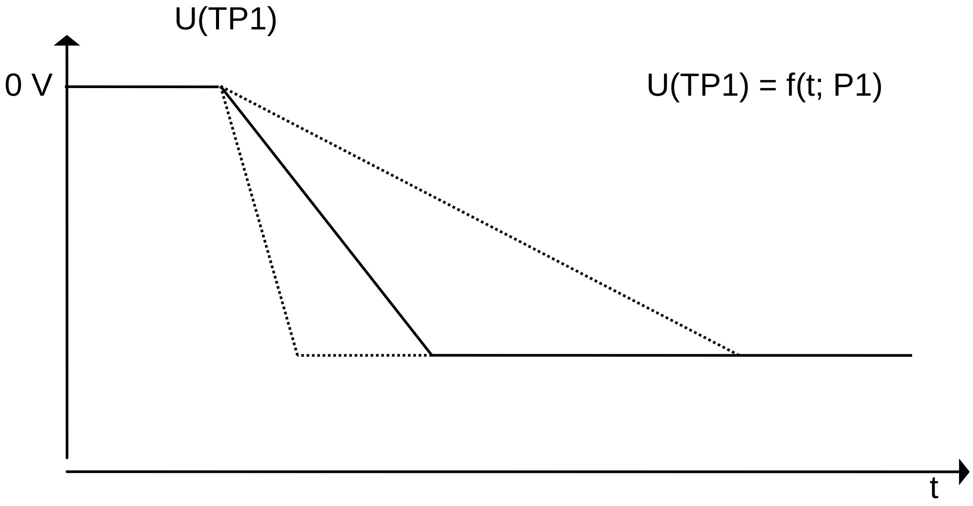


Fig. 6

After the rise time the input voltage must be reached. For fast applications remove jumper X1.

Note: This stage inverts the input signal.

Test point TP2, comparison point, servo ON only

After settling, this voltage must be zero.

Note: A permanent voltage indicates that somewhere in the servo-loop there is an undesirable limitation. (amplifier, PZT, sensor or controller)

Typical curve at positive input signal step.

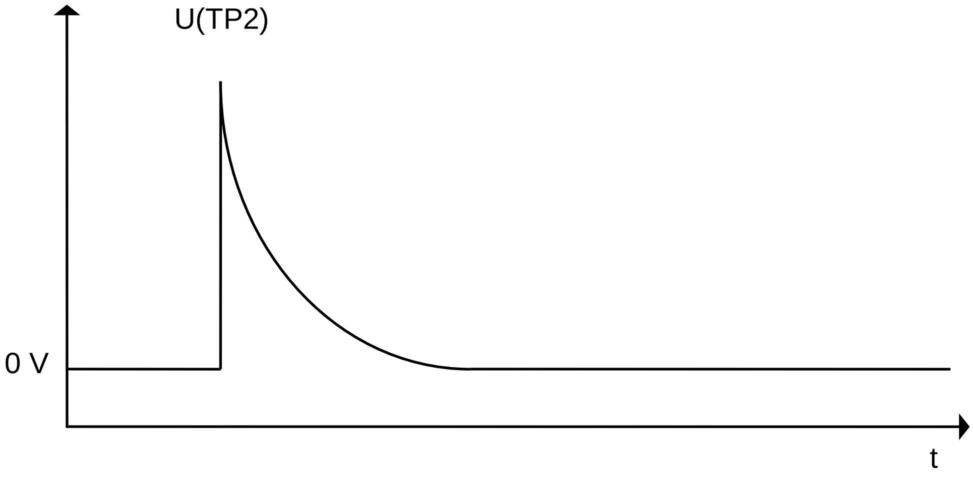


Fig. 7

Test point TP4, Notch, Servo ON only

Time response at input step depends on setting, example:

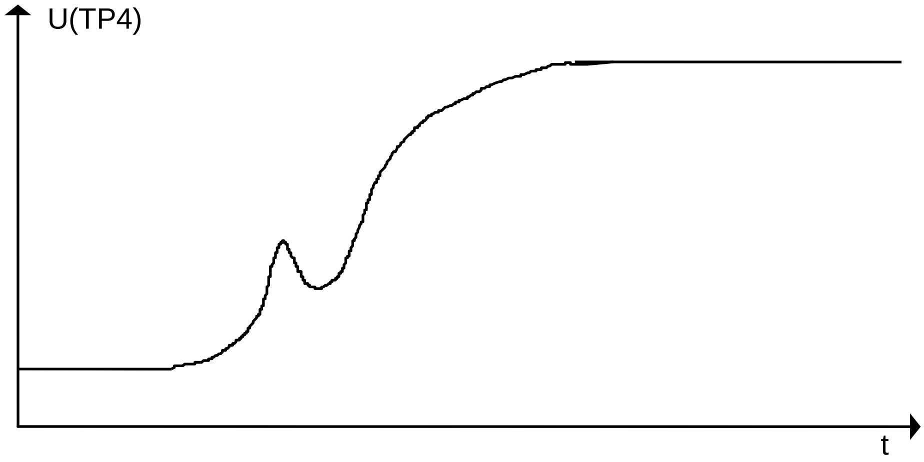


Fig. 8 Test Criterion: Final value equals input signal

2.9 Pinouts

The connectors J1 and J2 of all E-802 versions are pin-compatible, except as noted.

Connector J1

Pin	Signal	Meaning
1	LED_K	Overflow LED, cathode (-), normally 0 V = overflow
2	LED_A	Overflow LED, anode (+), normally always +5 V
3	GND	0 V
4	GND	0 V
5	VC/EC	Set servo OFF/ON
6	VC/EC	Set servo OFF/ON
7	Actual value	Current position (0-10 V)
8	Actual value	Current position (0-10 V)
9	VEE	-15 V
10	VEE	-15 V

Connector J2

Pin	Signal	
1	CTRL_OUT	Output to amplifier
2	ONT	If solder bridge SJ2 is closed (e.g. for E-621, E-625, E-665): On target (difference between current and target position is within ±0.19% of travel range), TTL active-low
3	COMMAND	Target, 0-10 V
4	OFL	Overflow, TTL, active-low
5	VCC	+15 V
6	VCC	+15 V
7	VEE	-15 V
8	VEE	-15 V
9	GND	0 V
10	GND	0V

3 Servo-Loop Calibration

Static servo-loop calibration makes it possible to accurately drive the PZT system to absolute positions in closed-loop mode with an external analog control signal ranging from 0 to +10 volts. This signal can either be input directly, or it can be generated by computer-control electronics in the system (e.g. E-816 Computer Interface and Command Interpreter).

Static servo calibration establishes the relationship between a sensor input of 10 V and the voltage necessary to drive the PZT to its nominal expansion.

Dynamic servo-loop calibration optimizes step response and suppresses resonance, overshoot, and oscillation (see section Dynamic Adjustment beginning on page 13).

Dynamic performance of the PZT system is determined by the maximum output current of the amplifier and by the mechanical properties of the PZT-mechanics like moving mass, damping and resonant frequencies.

In order to match the circuitry and the mechanical characteristics to achieve the desired performance, the system has to be adjusted for both static and dynamic operations.

The full calibration and adjustment procedure includes adjustment of the zero point, sensor gain, slew rate and step response. All these basic adjustments are done in our lab before shipment.

If PI has sufficient information about your application, your PZT system will be shipped ready for operation. Only the zero point will have to be realigned from time to time to compensate for temperature changes. Further adjustments are not required as long as system components are not replaced or modified.

Since open-loop sensor zero and range adjustment does not involve the servo-control module, it is described in detail in the other manuals accompanying this system.

During the calibration, the PZT actuator has to be connected to the device with which it is to be operated later: both devices then belong together. Replacement of a device requires new calibration run to get the specified system accuracy.

3.1 Equipment Needed for Calibration

For adjustment of the zero-point, a voltmeter is required.

Static displacement calibration requires an external expansion gauge with 0.1 µm resolution and a precision voltmeter. A special extension adapter may be required if your installation does not allow access to the potentiometers that need to be adjusted while the unit is in operation.

Dynamic calibration procedures require an oscilloscope (a digital storage oscilloscope is recommended) and a frequency generator to output square and sine functions from 1 Hz to 1 kHz. Depending on the installation, a 32-pin extension adapter board will also be necessary to allow access to the trim potentiometers while the board is in operation.

If the system is set up for computer control, it may be possible to use the internal wave generator and the internal D-to-A and A-to-D converters instead of the equipment mentioned above.

3.2 Preparations

Mount the PZT actuator in exactly the same way and with the same load as during normal operations in the application.

3.3 Zero-Point Adjustment

Correct zero-point adjustment allows the PZT to be used within the full displacement range without reaching the output voltage limits of the amplifier.

A proper zero-point calibration ensures that in closed-loop operation the full output voltage swing of the amplifier can be used and prevents overflow conditions.

Procedure:

1. Adjust the sensor zero point while servo mode is OFF as described in the manual for the controller (desktop unit, module or OEM board) on which the E-802.55 is installed.
2. Set servo mode to SERVO ON and make sure that the control input voltage is set to the value (target position) which is to correspond to 0 V PZT operating voltage. Normally this control input voltage value is 0 V[1].
3. Connect a voltmeter to the output socket for the PZT operating voltage.
4. Readjust the PZT operating voltage to 0 V using the ZERO potentiometer.

3.4 Static Gain Adjustment

The objective of the static servo-loop adjustment is to ensure that the PZT actuator expands to its nominal expansion when the control signal input is 10 V.

Preparations: An adjustable voltage source from 0 to +10.0000 V and a displacement gauge with 0.1 µm resolution is needed[2].

Procedure

1. Make sure that any DC-offset is set to zero or disabled (see main board manual).
2. Set SERVO ON mode.
3. Check whether the PZT oscillates. If it does, you can't miss hearing it, and dynamic gain adjustments have to be done prior to continuing with static gain adjustment.
4. Apply 0 V to the CONTROL INPUT.
5. Adjust the external position probe and set the expansion reading to zero.
6. Command a position equal to the nominal expansion (i.e. apply 10 V to the CONTROL INPUT). The external gauge should show the PZT at nominal expansion and the sensor monitor output should be 10 V.
7. To adjust the sensor monitor output to exactly 10.000 V use the P6 GAIN Fine Adjust potentiometer on the E-802.55 servo submodule.
8. To adjust the expansion without changing the sensor monitor output (servo-control is on!) use the gain adjustment potentiometer on the E-801.x sensor module.

Repeat the last steps several times until stable results are achieved.

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[1] In some cases, e.g. with the E-651 controller/amplifier for closed-loop bender actuators, the PZT operating voltage has to be 0 V if the control input voltage is -5 V.

[2] With bender actuators a non-contact measurement method must be applied.

4 Dynamic Adjustment

A summary of the equipment needed for adjustment can be found in section 3.1 on page 11.

4.1 Finding Resonant Frequency and Setting Notch Filter

Identify the resonant frequency of the actuator while installed at the operation site. For this purpose a square wave is applied to the control input with servo-control set to OFF (≈10 Hz, 1 Vpp, use DC offset 0.5 V if bipolar).

Connect the sensor monitor output with one channel of the oscilloscope and watch the step response. The resonant frequency of the system can be estimated by the induced oscillations. If, for example, the period of the oscillation is 3 ms, then the resonant frequency is 1/period length or 1/3 ms = 0.33 kHz or 330 Hz.

Based on this frequency, the dimensioning of the notch filter can be found in the table on page 6.

4.2 Step Response Optimization

4.2.1 Standard Tuning

For dynamic operation, the step response of the mechanical system is important. The amount of damping and overshoot can be optimized by tuning the differential and integral term of the servo controller.

Procedure

1. Mount the PZT exactly as it will be operated.
2. Set Servo ON.
3. Use a square wave function generator and supply the control input with a square wave of 5 Vpp (if bipolar, set DC offset to 2.5 V) and a frequency of 5 to 10 Hz.
4. Connect an oscilloscope to the monitor output.
5. Adjust P2 until resonant frequency becomes apparant.
6. Adjust P4 notch filter frequency until the oscillation amplitude becomes a minimum.
7. Adjust P2 and P3, alternating to optimize step response.

The settling curve seen on the scope could look like one of the following:

Case 1: Large overshoot, unstable

Case 2: Optimal

Case 3: Settling time too long

Sensor Monitor Signal:

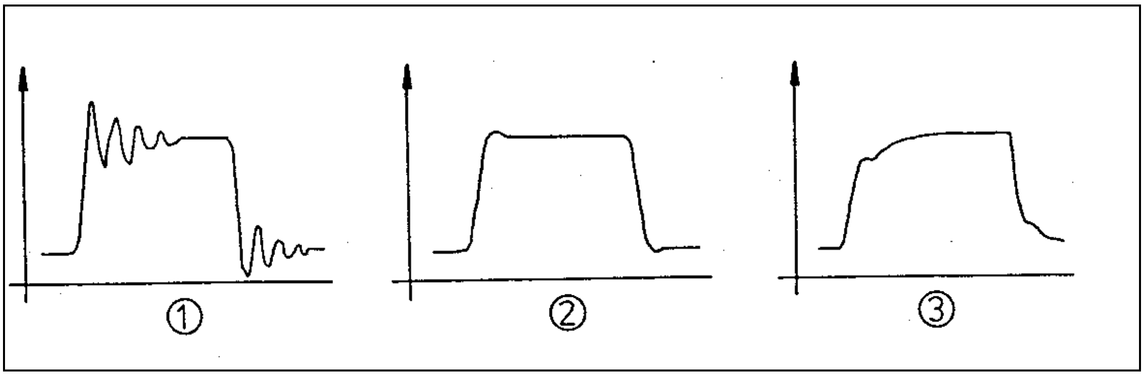

Fig. 9 PZT response

4.2.2 Fine Tuning

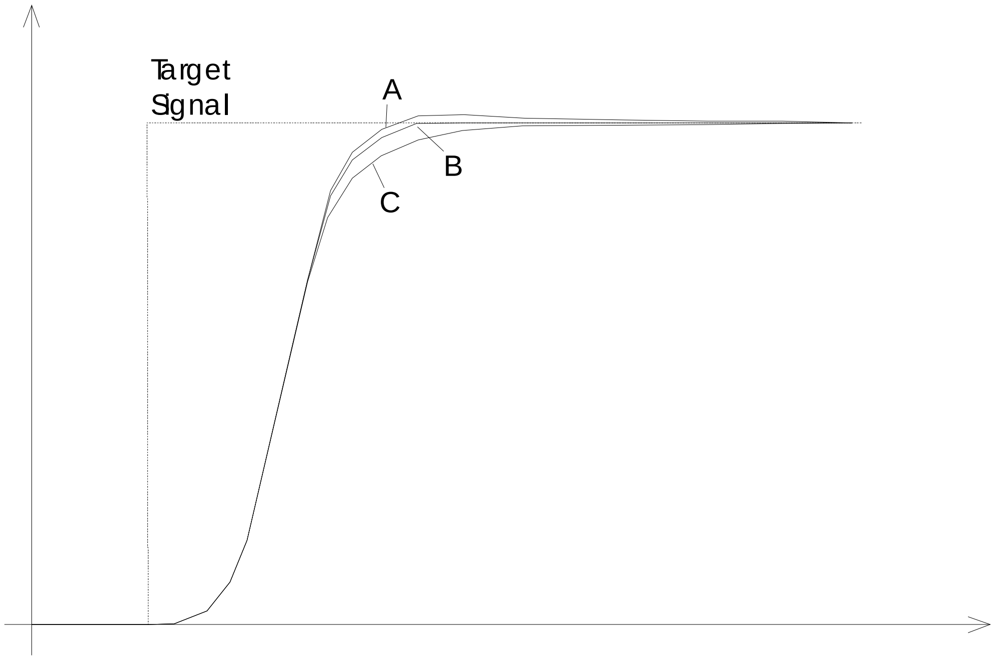

Fig. 10 Step response

The objective of the drift fine tuning is to obtain a curve similar to curve B of the diagram. Because the curve is exaggerated, a high-resolution oscilloscope (12-14 bits) is required as well as a precise voltage generator.

First, adjust the step response without overshoot. Using P5[3] (drift compensation potentiometer, for location see figure on p. 4) curve shapes A, B and C can be attained. If the overshoot can not be eliminated by using P5, the loop gain (P-term) has to be reduced.

The result may be different at rising and falling edges, so a compromise has to be found.

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[3] : By default P5 is preset to its mid position. In open-loop mode, the gain may vary by a value in the range of -3% to +6% depending on the setting of P5.