

HV-ADAPTOS

High-Voltage ADAPTive Optics
Supply System



TCP/IP Command Reference
and
EPICS IOC



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BEAMLINER ELECTRONIC INSTRUMENTATION



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Table Of Contents

1. INTRODUCTION.....	8
1.1 HV-ADAPTOS OVERVIEW.....	8
2. TCP/IP COMMANDS	10
2.1 COMMUNICATION PROTOCOL	10
2.1.1 <i>Commands Syntax</i>	10
2.1.2 <i>Reply Messages</i>	11
2.1.3 <i>ERROR Messages</i>	11
2.2 CONTROL OPERATIONS	12
2.2.1 <i>Group ON/OFF</i>	12
2.2.2 <i>Set Voltage</i>	12
2.2.3 <i>Shift Voltage</i>	13
2.2.4 <i>Target Voltages</i>	14
2.2.5 <i>Operation Mode</i>	14
2.3 READBACK OPERATIONS	16
2.3.1 <i>Output Voltage Readback</i>	16
2.3.1 <i>Status Readback</i>	16
2.3.1 <i>Target Voltage Readback</i>	17
2.3.1 <i>Output Voltage Readback</i>	17
2.3.1 <i>Output Current Readback</i>	18
2.3.1 <i>Operation Mode Readback</i>	18
2.3.2 <i>Temperature Readback</i>	19
2.3.3 <i>List of Groups</i>	19
2.3.1 <i>Number of Channels in a Group</i>	20
2.4 COMMAND REFERENCE.....	21
2.4.1 <i>SET Group commands</i>	21
2.4.2 <i>SET Channel commands</i>	21
2.4.3 <i>GET Channel commands</i>	22
2.4.1 <i>GET Group commands</i>	22
3. USAGE EXAMPLE.....	24
4. EPICS IOC	26

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High voltage inside, DO NOT open boxes

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Read over the instruction manual carefully before using the instrument.
The following precautions should be strictly observed before using the HV-ADAPTOS bipolar power supply system:

WARNING

- Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in this manual.
- Do not use the device if it is damaged. Before you use the device, inspect the instrument for possible cracks or breaks before each use.
- Do not operate the device around explosives gas, vapor or dust.
- Always use the device with the cables provided.
- Turn off the device before establishing any connection.
- Do not operate the device with the cover removed or loosened.
- Do not install substitute parts or perform any unauthorized modification to the product.
- Return the product to the manufacturer for service and repair to ensure that safety features are maintained

CAUTION

- This instrument is designed for indoor use and in area with low condensation.

The following table shows the general environmental requirements for a correct operation of the instrument:

Environmental Conditions	Requirements
Operating Temperature	5°C to 40°C
Operating Humidity	30% to 85% RH (non-condensing)
Storage Temperature	-10°C to 55°C
Storage Humidity	5% to 90% RH (non-condensing)



1. Introduction

This document is a reference manual for the TCP/IP commands for the HV-ADAPTOS multi-channel power supply system and contains information about the control and monitoring of the system via TCP/IP Commands.

1.1 HV-ADAPTOS Overview

The HV-ADAPTOS is a multi-channel High-Voltage (HV) bipolar power supply system especially developed to control, monitor and safely operate adaptive bimorph mirrors. The system is composed by a standard 19" - 4U crate containing a CPU board, integrated cooling, power supply sources and the HV boards.

Up to 6 independent A1522 ADAPTOS HV boards, each one housing 8 channels – rated at $\pm 2\text{kV}$ @ $\pm 0.5\text{mA}$ – can be installed into the system crate. Every HV board has dedicated passive internal protections that limit differential voltage between adjacent channel outputs to 500V. This behavior is required in order to protect the mirror from permanent damages and it allows safe operation of the overall optical system. Each A1522 ADAPTOS board also has an OVP (Over Voltage Protection) output and an OVP input connector in order to daisy-chain the differential protection – i.e. 500V – between channels of different boards. Other hardware-dedicated protections – e.g. passive emergency output discharging – are implemented for the specific application of adaptive X-ray mirrors.

The HV-ADAPTOS system includes an internal web server software dedicated to bimorph mirror control and monitoring and allows to simultaneously control more than one mirror with a single system.

The 8-channel boards can also be collected into different groups, each one associated with 8, 16, 24 or 32 number of electrodes. Three different levels of users' privileges (power user, user and generic) with different features and accessibility to configuring-setting-reading are implemented.

The possibility to dynamically assign individual HV channels to “super-electrodes” within the same group is also provided. Communication to the HV-ADAPTOS system is guaranteed by means of a 10/100/1000 Ethernet interface over standard TCP-IP protocol. EPICS drivers are integrated into the system crate and easily allow interfacing to the beamline control system.

The system also includes proprietary creep and hysteresis control and minimization routines.

HV-channels connected to the same mirror move in a coordinated manner in order not to make OVP trip during set point changes. External interlocks – e.g. vacuum – are accessible and configurable.



2. TCP/IP Commands

An explanation on how to control and monitor the channels on the HV-ADAPTOS power supply system via TCP/IP commands is hereafter presented.

The HV-ADAPTOS communicates via TCP/IP commands on port **5555** at the assigned IP address.

2.1 Communication Protocol

2.1.1 Commands Syntax

The TCP/IP commands that can be fed to the HV-ADAPTOS system have different syntax depending on the type of the command itself.

General structure of the command syntax follows:

- **SET Group commands**

GROUP<gr>:<command>[:value]

- **SET Channel commands**

GROUP<gr>:<command><ch>:<value>

- **GET Channel commands**

GROUP<gr>:<parameter><ch>?

Angle brackets – i.e. “< >” - denote a mandatory argument, while square brackets – i.e. “[]” – denote optional arguments. **DO NOT** include the brackets in the command.

The possible command arguments, referring to the previous general syntax structures are:

- *gr*: is the group number (starting from 0);
- *command*: is the name of the command;
- *parameter*: is the name of the attribute;
- *ch*: is the number of the channel (starting from 0);
- *value*: is a number or string that operates in the SET commands.

NOTE: each command must be terminated with the CR-LF sequence – i.e. “\r\n”.

Replies from the server have also the same CR-LF termination sequence.



2.1.2 Reply Messages

For each command sent to the TCP/IP server, the following reply messages are returned:

- Reply message to a GET command:

(A value of the required parameter)

- Reply message to a SET commands:

Command execution OK

In case of an error the reply message will begin with a “*** **ERROR**” string and it is completed with a description of the error as presented in the following section.

2.1.3 ERROR Messages

The possible error messages returned from the HV-ADAPTOS TCP/IP server are hereafter listed.

- *** **ERROR unknown command** is returned when a wrong command is sent from the TCP/IP client to the server;
- *** **ERROR command execution** is returned when a command cannot be executed;
- *** **ERROR command aborted: wrong group number** is returned when a non-existing group number is fed (a value out of range);
- *** **ERROR command aborted: wrong channel number** is returned when a non-existing channel number is fed (a value out of range);
- *** **ERROR command aborted: channel busy** is returned when the channel to which a sent command refers is already performing another operation;
- *** **ERROR command aborted: limit voltage violation** is returned when the voltage value set exceeds a pre-defined maximum threshold;
- *** **ERROR command aborted: unsafe voltage setting** is returned when the value of a new set voltage exceeds a pre-defined maximum differential threshold level that is stored internally in order to protect the mirror from damages;
- *** **ERROR command aborted: group is already powered on** is returned when the trying to turn on a group that is already in an ON state;

2.2 Control Operations

Multiple control operations, like managing the voltage output of the channels, can be performed on the HV-ADAPTOS. These operations can be specific for a single channel or can be applied to all the channels of a particular group.

It is necessary to wait until an operation generated by a command finishes – e.g. voltage set – before executing the next command.

2.2.1 Group ON/OFF

The ON/OFF operation allows to respectively switch ON or OFF all the channels of a specific group. The following command:

GROUP<gr>:ALL:ON

is used in order to turn ON all the channels of the <gr> group: the command execution will always set output voltages to zero level (0V). Sending the command:

GROUP<gr>:ALL:OFF

will instead turn all the channels of the <gr> group OFF, disabling the outputs.

Please note that powering OFF the output channels by feeding a GROUP<gr>:ALL:OFF command takes a certain amount of time since the output voltage does not turn off immediately but it is gradually ramped to a zero voltage level (0V). This procedure is performed in order to protect the connected mirror from damages.

2.2.2 Set Voltage

The output voltage set can be performed either on a single channel or on all channels.

The following command needs to be sent the HV-ADAPTOS power supply system in order to set the voltage output of a single channel:

GROUP<gr>:VOUT<ch>:<value>

The command to set all channel voltages of a single group to a common output value is the following:

GROUP<gr>:ALLVOLT:<value>

where: <gr> is the channel group number (starting from 0);
<ch> is the specific channel number;
<value> is the voltage value to be set, expressed in [V].

Please note that errors are returned if the $\langle gr \rangle$ group number or the $\langle value \rangle$ voltage is out of its respective range.

In both cases – i.e. setting the single channel or the entire group – the output voltage gradually moves from the current value to new set value $\langle value \rangle$.

The new set value for the voltage output is accepted only if included into pre-defined limits, thus included into a $[-V_{MAX}, V_{MAX}]$ range.

V_{MAX} is a constant voltage value and it is factory-configured based on the specific mirror configuration.

In the case of a single channel setting, the operation is allowed only if the absolute difference between the new set value and the voltage values of the physically adjacent channels do not exceed a constant parameter V_{GAP} .

The value of the V_{GAP} differential voltage is also factory-defined and it is usually set as $V_{GAP} = 500V$.

2.2.3 Shift Voltage

The voltage output can be also set by sending a relative shift value (with respect to the current one) for a single channel or for an entire group of channels.

The following syntax needs to be used in order to shift a particular channel by a $\langle value \rangle$ voltage:

GROUP $\langle gr \rangle$:SHIFT $\langle ch \rangle$: $\langle value \rangle$

A similar syntax, used to shift all channels of a particular group by a $\langle value \rangle$ voltage follows:

GROUP $\langle gr \rangle$:ALLSHIFT: $\langle value \rangle$

where: $\langle gr \rangle$ is the channel group number (starting from 0);

$\langle ch \rangle$ is the specific channel number;

$\langle value \rangle$ is the voltage value shift to be applied, expressed in [V].

Considering that the actual output voltage of a particular channel is V_{OLD} , after performing a “shift” voltage operation, the output will move to the new value $V_{OLD} + \langle value \rangle$:

$$V_{OLD} \rightarrow V_{OLD} + \langle value \rangle$$

An error message is generated if the new set value obtained using the voltage shift command exceeds the V_{GAP} (between the adjacent channels – i.e. adjacent electrodes on the mirror) or it is not included in the $[-V_{MAX}, V_{MAX}]$ interval.

Other error messages are generated if the group and/or channel values are not correct – e.g. out of range.

2.2.4 Target Voltages

The HV-ADAPTOS power supply system allows storing a desired value of voltage output – i.e. target voltage – for each channel; it is then possible to set the output voltage of each channel (or all of them) to this previously stored value.

The following command syntax needs to be used in order to store the target voltage value for a specific channel:

GROUP<gr>:VTRGT<ch>:<value>

The command that sets all channels of a group to the previously stored target voltages is:

GROUP<gr>:ALLTRGT

where: <gr> is the channel group number (starting from 0);
<ch> is the specific channel number;
<value> is the target voltage value to be stored, expressed in [V].

The operation is performed if the values of these target voltages are compliant with same rules previously described – e.g. adjacent channels cannot have a voltage difference greater than the constant parameter V_{GAP} .

2.2.5 Operation Mode

The HV-ADAPTOS power supply system has different operation modes. A specific command is implemented in order to set the operation mode for a group of channels to the desired one.

The following command syntax needs to be used in order to set the desired operation mode:

GROUP<gr>:OPMODE:<mode>

where: <gr> is the channel group number (starting from 0);
<mode> is the operation mode to be set.

The operation mode needs to be an ASCII string associated with the desired operation mode for the group and can be one of the following:

- **HI**: sets the operation mode to high-resolution;
- **NORMAL**: sets the group to normal operation mode;
- **FAST**: sets the group of channels to fast operation mode.

An error message is returned if the <gr> group number is not valid (or is out of range) or if the <mode> is not one of the ASCII strings presented above.

Example: by sending to the TCP/IP server the following string:

GROUP0:OPMODE:HI

the operation mode for the channels associated to the group #0 is set to high-resolution operation.



2.3 Readback Operations

Multiple readback operations are available on the HV-ADAPTOS power supply system. Some of them are hereafter presented.

2.3.1 Output Voltage Readback

The single channel set output voltage can be read by sending a command with a similar syntax with respect to the “set” operation.

GROUP<gr>:VOUT<ch>?

where: <gr> is the channel group number (starting from 0);
<ch> is the specific channel number.

Please note that errors are returned if the <gr> group number or the <ch> number is out of its respective range.

The returned string from the server is:

<value>

where <value> is an ASCII string containing the value of the actual set output voltage, expressed in [V].

2.3.1 Status Readback

The status of a single channel in the HV-ADAPTOS system can be monitored by sending the following command:

GROUP<gr>:STATUS<ch>?

where: <gr> is the channel group number (starting from 0);
<ch> is the specific channel number.

Please note that, as previously presented, errors are returned if the <gr> group number or the <ch> number is out of its respective range.

Replies from the HV-ADAPTOS server are in the following format:

<status>

where <status> is an ASCII number that corresponds to a particular channel status. The possible values for the status register are the following:

<i><status></i>	Description
0	The channel is OFF
8	The channel is ON
16	The channel is busy (performing other operations)
32	The channel has experienced a fault/alarm

The *<status>* = 32 condition arises when a fault or alarm condition has been experienced – e.g. an interlock trip, an over-voltage or an under-voltage condition. Detailed information on the type of active fault/alarm is available on the HV-ADAPTOS web interface.

2.3.1 Target Voltage Readback

As previously described, each channel of each group in the HV-ADAPTOS can be assigned to a target voltage defined by the user.

The actual stored value for the target voltage of a single channel can be read by sending the following command:

GROUP<gr>:VTRGT<ch>?

where: *<gr>* is the channel group number (starting from 0);
<ch> is the specific channel number.

Please note that errors are returned if the *<gr>* group number or the *<ch>* number is out of its respective range.

The returned string from the server is:

<value>

where *<value>* is an ASCII string containing the actual value of the target voltage for the *<ch>* channel and it is expressed in [V].

2.3.1 Output Voltage Readback

This command allows to read the actual output voltage readback on each channel of each group in the HV-ADAPTOS system. To read the voltage output of a single channel, the following command has to be used:

GROUP<gr>:VMON<ch>?

where: $\langle gr \rangle$ is the channel group number (starting from 0);
 $\langle ch \rangle$ is the specific channel number.

Please note that errors are returned if the $\langle gr \rangle$ group number or the $\langle ch \rangle$ number is out of its respective range.

The returned string from the server is:

$\langle value \rangle$

where $\langle value \rangle$ is an ASCII string containing the actual value of the output voltage for the $\langle ch \rangle$ channel and it is expressed in [V].

2.3.1 Output Current Readback

This command allows to read the actual output current readback on each channel of each group in the HV-ADAPTOS system. The command has the following form:

GROUP $\langle gr \rangle$:IMON $\langle ch \rangle$?

where: $\langle gr \rangle$ is the channel group number (starting from 0);
 $\langle ch \rangle$ is the specific channel number.

Please note that errors are returned if the $\langle gr \rangle$ group number or the $\langle ch \rangle$ number is out of its respective range.

The returned string from the server is:

$\langle value \rangle$

where $\langle value \rangle$ is an ASCII string containing the actual value of the current voltage for the $\langle ch \rangle$ channel and it is expressed in [uA].

2.3.1 Operation Mode Readback

The following command syntax needs to be used in order to check the configured operation mode for a specific group of channels:

GROUP $\langle gr \rangle$:OPMODE?

where: $\langle gr \rangle$ is the channel group number (starting from 0).

Replies from the TCP/IP server to a correct command are in the following form:

$\langle mode \rangle$

where *<mode>* is an ASCII string indicating the operation mode and can be one of the following:

- **HI**
- **NORMAL**
- **FAST**

An error message is returned if the *<gr>* group number is not valid or if it is out of range.

2.3.2 Temperature Readback

Each A1522 ADAPTOS board, housing 8 HV channels, has an internal temperature sensor for monitoring the correct operation of the HV channels and the electronics.

These temperature values can be monitored by sending a command to the TCP/IP server in the following format:

GROUP<gr>:TEMP?

where: *<gr>* is the channel group number (starting from 0).

Depending on the number of channels associated to the corresponding *<gr>* group, and thus on the number of the A1522 ADAPTOS boards associated to it, the reply can be in different formats. If only one HV board is associated with the group *<gr>*, then the reply will be in the following form:

<temp1>

In the case of multiple boards associated to the group *<gr>*, the temperature values are separated by a semicolon “;” symbol and are in the following form:

<temp1>;<temp2>; ...

where *<temp1>* and *<temp2>* are temperature values, in [°C], represented as ASCII strings.

An error message, as in other cases, is returned if the *<gr>* group number is not valid or if it is out of range.

2.3.3 List of Groups

The HV-ADAPTOS can have multiple groups of channels configured on the same system.

It is possible to have a list of defined groups of channels by sending the following command to the TCP/IP server:

:GROUPSLIST?

The replies to the TCP/IP client are in the following form:

<ID1>;<ID2>; ...

where <ID1> and <ID2> are the identification numbers of the configured groups, separated by a semicolon “;” symbol.

An empty string is returned if no groups are actually configured on the HV-ADAPTOS system.

2.3.1 Number of Channels in a Group

The total number of group associated to a single <gr> group can be monitored by sending the following command:

GROUP<gr>:CHANNELS?

where <gr> is the group identification number. Configured group identification can be found by sending the **:GROUPSLIST?** command to the TCP/IP server (see previous section for further details).

Replies from the TCP/IP server are in the following format:

<N_channels>

where <N_channels> is the number of channels associated to the <gr> group and it is represented as an ASCII string.

2.4 Command Reference

A brief list of some of the available commands for the HV-ADAPTOS power supply system is hereafter presented.

2.4.1 SET Group commands

GROUP<gr>:ALL:ON	Switches ON the group. <i>Note:</i> the voltage output for all channels are set to zero.
GROUP<gr>:ALL:OFF	Switches OFF the group.
GROUP<gr>:RESETERR	Resets the alarm condition for group.
GROUP<gr>:ALLVOLT:<value>	Sets the voltage output for all channels of group.
GROUP<gr>:ALLSHIFT:<value>	Shifts the voltage output for all channels of group.
GROUP<gr>:ALLTRGT	Sets the voltage output with the voltage target stored for each channel of group.
GROUP<gr>:OPMODE:<mode>	Sets the operation mode for the group. <mode> needs to HI, NORMAL or FAST

2.4.2 SET Channel commands

GROUP<gr>:VOUT<ch>:<value>	Sets the voltage output for the channel.
GROUP<gr>:SHIFT<ch>:<value>	Shifts the voltage output for the channel.
GROUP<gr>:VTRGT<ch>:<value>	Stores the voltage target for the channel.

2.4.3 GET Channel commands

GROUP<gr>:VOUT<ch>?	Returns the value of the voltage output target.
GROUP<gr>:VMON<ch>?	Returns the value of the output voltage.
GROUP<gr>:IMON<ch>?	Returns the value of the output current.
GROUP<gr>:STATUS<ch>?	Returns a status value for the channel. The possible state value are: 0: Channel is OFF 8: Channel is ON 16: Channel is busy 32: Channel fault/alarm
GROUP<gr>:VTRGT<ch>?	Returns the value of the stored target voltage.

2.4.1 GET Group commands

GROUP<gr>:OPMODE?	Returns the actual operation mode of group <gr>.
GROUP<gr>:TEMP?	Returns the measured temperature values of the HV boards associated with the group <gr>. In case of multiple boards, values are separated by a “;”.
:GROUPSLIST?	Returns the ID list of the configured groups. IDs are separated by a “;” symbol. An empty string is returned if no groups are configured.
GROUP<gr>:CHANNELS?	Returns number of channels associated to group <gr>.
GROUP<gr>:STATUS?	Returns a status value for the group <gr>. The possible state value are: 0: Group is IDLE 1: Group is BUSY

GROUP<gr>:ERR?

Returns a status of alarm condition for group.

0: NO ERROR

1: ERROR/ALARM



3. Usage Example

A usage example is herein presented. Commands sent from the TCP/IP client are listed in the left column while the replies from the server are on the right one.

This example considers a situation where a group with 12 channels is configured with the group identifier 0.

GROUP0:RESETEERR →	← Command execution OK
GROUP0:ALL:ON →	← Command execution OK
GROUP0:STATUS0? →	← 8
GROUP0:ALLVOLT:250 →	← Command execution OK
GROUP0:ALLSHIFT:-50 →	← Command execution OK
GROUP0:VOUT0? →	← 200
GROUP0:VOUT0:300 →	← Command execution OK
GROUP0:VOUT0? →	← 300
GROUP0:VOUT11? →	← 200
GROUP0:SHIFT11:50 →	← Command execution OK
GROUP0:VOUT0? →	← 300

GROUP0:VOUT1? →	←	200
GROUP0:VOUT11? →	←	250
GROUP0:ALL:OFF →	←	Command execution OK
GROUP0:STATUS0? →	←	0

In order to acknowledge the system full capabilities you can connect to the CAENELS website - www.caenels.com – and download the HV-ADAPTOS User's Manual.

Please also refer to the specific HV-ADAPTOS product page to check for new firmware and software releases.

4. EPICS IOC

A direct correspondence between TCP/IP commands and the internal EPICS IOC process variables is hereafter presented in the following table. The description of each command can be directly retrieved from the previous sections of this manual.

EPICS PV	TCP Command
<GROUPNAME>:GET-STATUS	<GROUPNAME>:STATUS?
<GROUPNAME>:GET-MODE	<GROUPNAME>:OPMODE?
<GROUPNAME>:GET-LASTERR	<GROUPNAME>:ERR?
<GROUPNAME>:SET-ALLVOLT	<GROUPNAME>:ALLVOLT:<value>
<GROUPNAME>:SET-ALLTRGT	<GROUPNAME>:ALLTRGT
<GROUPNAME>:SET-ALLSHIFT	<GROUPNAME>:ALLSHIFT:<value>
<GROUPNAME>:SET-ALLOFF	<GROUPNAME>:ALL:OFF
<GROUPNAME>:SET-ALLON	<GROUPNAME>:ALL:ON
<GROUPNAME>:RESET-LASTERR	<GROUPNAME>:RESETERR
<GROUPNAME>:SET-MODE	<GROUPNAME>:OPMODE:<value>
<GROUPNAME>:GET-STATUS<N>	<GROUPNAME>:STATUS<N>?
<GROUPNAME>:GET-VTRGT<N>	<GROUPNAME>:VTRGT<N>?
<GROUPNAME>:GET-VOUT<N>	<GROUPNAME>:VOUT<N>?
<GROUPNAME>:SET-VOUT<N>	<GROUPNAME>:VOUT<N>:<value>
<GROUPNAME>:SET-VTRGT<N>	<GROUPNAME>:VTRGT<N>:<value>
<GROUPNAME>:SET-SHIFT<N>	<GROUPNAME>:SHIFT<N>:<value>