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Description of Modifications

The following includes a description of all modifications to the Secondary Mirror Alignment System till April 1996. This document belongs as supplement to the MS43E document and includes modified chapters only.

3.0 Mechanics

3.1 Tilting Mirror Unit

Thermal testing of the final mirror mounted to the mechanics has shown residual stress inside the mirror mounts resulting in bending of the mirror. To reduce thermal induced stress the INVAR mirror mounting plate was modified according a recommendation of IFA (see attached drawings S-915077-101 and S-915077-132). Four stainless steel flexures with a length of 14.4 mm each were added to the radially compliant mirror mounting pads (laser welded) to adapt the average CTE of steel and INVAR to the CTE of SiC the mirror is made from.

At the same time the mirror mounting was changed to simplify mounting/ dismounting procedure. All three mirror posts include now a tip/tilt degree of freedom and two of them an additional radially translation DOF (see attached drawing S-915077-115 and S-915077-131).

The interface plane between the posts and the mirror mounting plate is modified by an additional INVAR part (drawing S-915077-130) welded to the back side of the mirror mounting plate. It is grinded and has a small out of plane tolerance. Together with the integrated tip/tilt DOF of the posts even a repeated mounting/dismounting with minimum stress to the mirror should be possible. To fix the mirror posts to the mounting plate three M5 screws (unloosable) are used now instead of M6 nuts.

3.2 Mirror Mounting/Dismounting Procedures

The design of the TM-UNIT allows to carry out all testing and calibrating procedures independent of the kind of the mirror mounted. An aluminum dummy mirror was used for testing with the same shape and about the same moment of inertia as the final mirror substrate.

To avoid any mechanical stress in the mirror substrate, the last step of the mounting procedure is to glue to mirror onto the post-flats. After that, no screw must be touched. This general rule may be broken if an mounted mirror is dismounted and later reinstalled with the same posts glued on the substrate. In that case, the mirror should be mounted in the same orientation and the three M5 screws should be tightened with equal torque.

Dismounting Procedure

1. The mirror is mounted via three posts on the *mirror mounting plate. Unscrew the metric M5 screws (13) at the bottom side of the mirror mounting plate.* Reach through the free center space to the three M5 screws at the *post mounting pads* and use an Allen key tool to unscrew the screws.
2. Unlock the three safety hooks (6) with an Allen key, tilt it to the center position and lock it again.

3. Carefully lift off the mirror with the glued-on INVAR posts from the *mirror mounting plate*. Avoid tilting.

Mounting Procedure

1. Mount the three INVAR posts to the post mounting pads on the *mirror mounting plate* using the three integrated metric M5 screws. Keep attention to the orientation of the two posts with integrated linear DOF . Please make sure that during gluing the posts to the mirror the orientation of the translation DOF is radially to the third post and not to the mirror center!
2. Glue the mirror onto the INVAR posts. This should be carried out while all components are at room temperature. Note that centering of the mirror is necessary and also the angular orientation has to comply with the safety hooks at the base structure.
3. Lock the safety hooks again in its most radial position.

3.3 HEXAPOD Unit

The HEXAPOD unit was modified as follows:

1. All moving parts inside the HEXAPOD legs (especially the gear heads) were cleaned and lubricated with KLÜBER LUBRICATION ISOFLEX LDS18 SPECIAL A. This is a special low temperature lubricant to ensure low viscosity and low motor current up to -10°C operation temperature.

2. To avoid mechanical crash during possible malfunction of the HEXAPOD Controller or optical limit switches additional mechanical limit switches were integrated inside each HEXAPOD leg to break the motor current direct if touched. This requested a slightly larger diameter of the HEXAPOD legs and a small change at the connector holder and the base plate.

3. Flexible wires were added between the HEXAPOD base plate and the Mirror Unit to prevent mechanical parts from falling down to the primary mirror in case all other safety features would fail.

5.0 Electronics

5.2. HEXAPOD Controller (*HEXC*)

5.2.1 DC-Motor-Controller

One of the major tasks of the H8/534 microprocessor is to transform the motion command parameters based on the orthogonal coordinate system into the relative length changes of the six HEXAPOD leg. All six target positions with the corresponding velocities are calculated and transferred to both DC-motor controller DSP-modules (part of the HEXAPOD controller).

The HEXAPOD controller (HEXC) performs the following functions:

1. Reading and transferring the analog position data for both tilting mirror axes within 100 µs intervals.
2. Parsing and execution of HEXC commands by the host interface receiving data via serial data link.
3. Data link layer with communications, traffic control and data verification on Uplink.
4. Coordinate transformation for HEXAPOD translations and rotations.
5. PID-control of all motor axes
6. System state verification within 200 ms cycles

Communication interfaces on the host (RS-232) and for the data link (RS-422) have the same priority and are not alternatively disabled. The RS-232 interface enables the text output mode when receiving the first LineFeed (ENTER, 0Ah). The text output mode is disabled when receiving the QUIT command or after reset.

Otherwise the missing handshake signal and internal buffer overflow delays the command processing. The transmission of the sensor information is not concerned.

For motion control of the six HEXAPOD axes and the two auxiliary motors two fast specialized chipsets (4 axes per chipset) is used with 500 µs servo loop update time. Each axis is interfaced by two quadrature encoder signals, two limit switch signals (right/left) and one reference TTL signal. During command processing the logical (geometrical) axes are assigned to the physical axes.

Logical Axis	Physical Axis	Controller #
1	0	1
2	1	1
3	2	1
4	0	2
5	1	2
6	2	2

7	3	2
8	3	1

The reported values for limit, reference and axis number using the STAT command refer to the physical axes. The output signal is given with a resolution of 12 bits. The limit switches for the two auxiliary axes are defined as low-active.

Optical limit switch hit events cause immediate stop of the referred axis and then the software moves the motor back until the limit switch released. This procedure may cause errors in the current position counter and therefore new initialization is required if any of the 6 axes hits the limit.

The amplifier for each axis has 3 Watts average output power at 12 Volts. After reaching the target position and if there is no new command to be executed, the motors are shut off (servo loops are suspended) after 5 seconds in order to save power and to avoid heating.

Inherent self blocking of the spindle avoids any undesired motion. If the position is changed anyway, there may occur abrupt motions after a new move command is issued.

Following modifications were done:

The most used operation mode for the HEXAPOD is piston movement for focus adjustment. Because all HEXAPOD legs are wired identical and moving parallel a high peak current is needed either from the +15V or from the -15V power supply at this mode. To come to a better power sharing axis 1, 3 and 5 are rewired inside the HEXAPOD Controller so that each power supply has to deliver half of the current during piston movement. This ensures also a higher safety margin at very low operation temperatures were higher currents are needed.

5.2.3 RS-422 Data Link

Serial data communication is used for digital data transfer from the sensors as well as for HEXAPOD commands and status information. Data transfer from HEXAPOD controller to the MPIC controller (downlink) occurs periodically each 100 µs with data bursts (2x16 bit sensor data in 2´s complement and no validity control and 2x8 bit status and multiplex data).

Handshake loss or time-outs during the downlink process cause a reset in the concerned module after 10 ms and then the data transfer is started over again. The servo control is suspended during that time and the last state of the PZT controller is maintained.

Command transmission from the HEXC to the MPIC controller (uplink) is handled by a multi level protocol. Data packages are verified by the CRC-CCITT generator polynom and are repeated up to 10 times if the transmission fails. In the case the error is still there or if the 500 ms time-out is expired, an error message is issued. Missing handshake during the uplink causes a reset of the module after 5 ms and then data transmission is resumed. During these error handling procedures the downlink transmission is not influenced and stays in operation.

5.3 User Interfaces

5.3.1 MP-UNIT Controller

Parallel Inputs: U-IN, V-IN

If the servo loop is shut off, the digital target positions (TTL level) at the parallel inputs are loaded directly into the D/A Converters (DAC) after the coordinate transformation. Changes of the position values through the parallel interface are not limited by any slew rate.

Sensor position data are processed internally with 0.002 arcsec = LSB resolution and are interpreted as 16 bit values in two´s complement notation. The value is latched at the low-high edge of the strobe signal. The strobe signal lines for U-IN and V-IN can be tied together by the jumper U048.

Connector: DB37, male

Parallel / Analog Input CTRL-INP:

Data at CTRL-INP control states of the system and are equivalent to the commands given from the serial host interface. Following states can be set:

- servo on/off
- piezo on/off
- compensation on/off
- external control on/off

Data latching occurs with the low-high edge of the strobe signal. The strobe input lines for CTRL-INP, U-IN, V-IN can be tied together internally by the jumper U0140. The latched values can be read as echo at CTRL-OUT.

All control bits are low active. With EXT-CTRL=low the PZT amplifiers are fed with the external analog position values AU-IN and AV-IN (-5 .. +5 Volts).

At external control=on two analog inputs from pin 12,13 are fed to an analog coordinate transformation network to drive the PZT power amplifier direct in open loop for minimum phase delay. This mode is not supported by the digital control capabilities!

Connector: DB25, male

Parallel Outputs U-OUT, V-OUT:

Digital position values transferred during the download process are available at the parallel outputs U-OUT and V-OUT with TTL level.

Valid new position data are indicated by the high pulse on the strobe line with a time delay of 15 µs between the U- and the V- position. The values are updated with 100 µs cycle time independent of the state of the system.

Connector: DB37, female

Parallel Output AUX-OUT

The system status of the HEXAPOD controller is available at the AUX-OUT line with following bit assingment:

```
#define HEXAPOD_RUNNING            0x01    /* HEXC status flags */
#define HEXAPOD_TARGET_REACHED     0x02
#define HEXAPOD_REFERENCING        0x04
#define HEXAPOD_REFERENCED         0x08
#define HEXC_BUSY                  0x10
#define HEXC_COMMAND_ERROR         0x20
#define HEXC_GEOMETRY_ERROR        0x40
#define HEXC_SYSTEM_ERROR          0x80
```

Connector: DB37, female

Parallel / Analog Output CTRL-OUT:

This output is used for output TTL information regarding MPIC system status information. In addition RET-AUTO-MOVE pulse indicates the start point of internal generated tip-tilt waveforms for testing purposes (sine or chop).

The pins AU-OUT and AV-OUT output the amplified analog sensor values in the range of -10 to +10 Volts (+/- 50 arcsec is appr. +/- 6.5 Volts).

Connector: DB25, female

Serial data link (RS-422):

10 MBit/s, asynchronous according Transputer Link

Connector: LEMOSA, 16 Pin female

6.0 Programming and Software

6.2. Command Protocol

MPIC and HEXC controllers are working asynchronously. The receiving of a HEXAPOD command by the MPIC does neither reflect processing nor execution of the command by the HEXC.

Processing of a command by the HEXC is indicated by the HEXC_BUSY bit of the HEXC_STATUS. A new command for the HEXC should only be given if this bit is reset. Otherwise a COMMAND_ERROR is set.

A HEXC_CMD_ERROR is also created if a new motion command is given while the HEXAPOD or a single axis is still running . In this case the HEXAPOD or single axis should stopped first.

All commands are sent as ASCII characters with line feed (LF, 0x0a) as terminator. Upper- or lower case characters are allowed. Correction of sent characters is not possible and all edit functions have to be performed by the terminal program.

Command name and parameters as well as parameters themselves are separated by spaces. All parameters are optional and are indicated by a leading parameter label. In between that and the parameter itself only an optional sign is allowed.

The HELP command gives you a list of all available commands and optional parameters.

After receiving the terminator character, the command line is parsed regarding

- Length of the line
- Implementation of the command
- Validity of the parameter(s)
- Format of the parameter(s)

The maximal length of the command line is 80 characters.

Errors within the command line are marked and the complete line is disregarded.

Floating point values are internal represented in the TMS320C3x format with 24 bit mantissa and 6 decimal digit of precision.

6.3. Command Set

6.3.1. Command Set of MPIC Controller

The *-marked commands contain MPIC controller specific information

Tilting Mirror Commands:

MROT {UV}	Rotate TM-UNIT platform absolute around U,V- axis [rad]
MPOS	Report TM-UNIT angular position [rad]
MSSR {S}	Set or report slew rate for TM-UNIT tip/tilt movement [rad/s]
MPID {PIDGFRLA}	Set or report TM-UNIT PID- ,notch filter and lead compensator parameter
MCMP {UV}	Set momentum compensation gain factors
MCHP {ABCDT}	Set or report chopping angle: Umin,Umax,Vmin,Vmax [rad], delay T [ms]
MSIN {UVF}	Set or report sin-wave amplitude U,V [rad], frequency F [Hz]
MCMP {UV}	Set momentum compensation gain factors

HEXAPOD Commands:

HMOV {XYZRSTUVW}	Move HEXAPOD absolute in X,Y,Z- axis, define the center of rotation at point R,S,T, rotate around U,V,W- axis [mm,rad]
HVEL {V}	Set or report HEXAPOD velocity parameter [mm/s]
HREF	Initialize HEXAPOD position at reference position
STOP	Abort HEXAPOD motion

Auxiliary Motor Commands:

XPOS {nP}	Move auxiliary motor to position P [counts], axis #n
XPAR {nVA}	Set auxiliary motor motion parameter, axis #n, velocity [counts/T], acceleration [counts/T/T]
XPID {nPIDL}	Set auxiliary motor control parameter for axis #n, PID-parameters, integration limit L

System Commands:

SETF {PSCAX}	Sets or reports TM-UNIT system control flags for: piezo actuators, servo loop, momentum compensation, auto-move mode (sin, square or chopping), external analog input
STAT* {N}	Report MPIC, HEXC, HEXAPOD or axis status
REST* {N}	Restart MPIC or HEXC
HELP*	Reports list of available commands

6.3.2. Service Command Set for HEXAPOD Controller (HEXC)

The following commands can be used in case of service or installation of the HEXAPOD unit if some basic operation and status information is needed while working on the top end of the telescope. In this case a Notebook-PC could be connected to the standard RS-232 serial link of the HEXAPOD controller running a simple ASCII terminal emulator program. The MPIC controller must be powered on to supply all needed voltages.

The *-marked commands contain HEXAPOD- controller specific informations

Tilting Mirror Commands:

None

Hexapod Commands:

HMOV{XYZRSTUVW}	Move HEXAPOD absolute in X,Y,Z- axis, define center of rotation at point R,S,T, rotate around U,V,W- axis, [mm,rad]
HVEL {V}	Set or report HEXAPOD velocity parameter [mm/s]
HREF	Initialize HEXAPOD position at reference position

Auxiliary Motor Commands:

XPOS {nP}	Move auxiliary motor to position P [counts], axis #n
XPAR {nVA}	Set auxiliary motor motion parameter, axis #n, velocity [counts/T], acceleration [counts/T/T]
XPID {nPIDL}	Set auxiliary motor control parameter, axis #n, PID-parameter, integration limit

System Commands:

STAT* {N}	Report system status
HELP* {L}	Reports list of available commands
REST*	Restart HEXC
QUIT*	Stops communication

6.3. Command Reference

MROT {param}[value] Rotate Mirror Absolute

This command tilts the *mirror mounting platform* of the TM-UNIT to an absolute position around the axes U,V with a resolution of 10 nrad. Internal used angular increments are 10 nrad.

Parameter:	U,V
Format:	Float
Value:	-225e-6 ... +225e-6 (rad)
Example:	**MROT U10E-6 V-5.3e-6**
Function:	*Rotates the TM-UNIT platform 10.0 µrad in U and -5.3 µrad in V direction*

MPOS Report Mirror Position

This command causes the MPIC controller to report the commanded and current Tip/Tilt position of the TM-UNIT , detected by the KAMAN sensors. Reported values are read in „rad“ for the tilting axes U and V.

Format:	Float
Result:	-225e-6 ... +225e-6 (rad)

MSSR {param}[value] Set or Report Slew Rate

This command defines the slew rate limit for the TM-UNIT. The maximum allowed value for the parameter S is 0.01 rad/s because of the current limitation of the PZT power amplifiers. If no parameter S is specified, this command reports the actual slew rate setting.

Parameter:	S
Format:	Float
Value:	0 ... 0.01 (rad/s)

MPID {param}[value] Set or Report Mirror PID- Filter Parameters

This command defines the PID filter parameter used for the TM-UNIT. Furthermore a parameter G is available, limiting the D-term at high frequencies. In order to attenuate the first mechanical resonance frequency an additional Notch filter algorithm is implemented, which realizes a rejection of R at the frequency of F. If no parameters are specified, this command reports the actual PID- filter settings.

Parameters: **P, I, D, G, F, R, L, A**

Format: Float

Value: Default values:

P= 0.012
I= 0.000016
D= 0.000002
G= 0.00002
F= 520
R= 0.59
L= 300
A= 2.0

MCHP {param}[value] Set or Report Chopping Parameter

This command defines the parameters for the Chopping mode. The parameters A and B define the Max. and Min. limits of the tilting angle in U direction, parameters C and D in V direction.

The angular units for the parameters are in rad.

The delay time before switching to the opposite angle position is T in ms including the settling time. Parameters become active when the command SETF A1 is issued. If no parameters are specified, this command reports the actual chopping parameter settings.

Parameter: A,B,C,D,T

Format: Float

Value: A=B=C=D -225e-6 ...+225e-6 (rad)

T (ms)

Example: **MCHP A-7.07e-6 B7.07e-6 C7.07e-6 D17.07e-6 T50**

This example defines a square wave function with a frequency of 10 Hz, an amplitude of 10.0 µrad and an offset of 10.0 µrad in the V-axis. The resulting tilting axis is the diagonal line in the UV plane.

MSIN {param}[value] Set or Report Sine- Wave Parameter

This command sets the sin-wave parameter amplitude U,V in rad, frequency F in Hz for an internal generated test signal. If no parameters are specified, this command reports the actual sine- wave parameter settings.

Parameters: U,V,F

Format: Integer

Value: U=V - 225e-6 ... + 225e-6 (rad)

F 1.0 ... 2500.0 (Hz)

Example: **MSIN V20.5e-6 F25**

defines a sine wave tilt movement around the V- axis with an amplitude of 20.5 µrad and 25 Hz.

MCMP {param}[value] Set or Read Momentum Compensation Gain

This command can be used to fine tune the momentum compensation. In case of gain=1, the momentum compensation piezos are driven with identical amplitudes as the mirror actuators. To optimize the performance with the final mirror or to compensate tolerances of piezo expansion a value different from 1 may be required for each individual axis U or V. If no parameters are specified, this command reports the actual compensation gain factor settings.

Parameter: U,V

Format: Float

Value: 0.8 ... 1.2 default = 1

HMOV {param}[value] Move HEXAPOD Absolute

This command is used to move the HEXAPOD system in six axes at the same time by coordinates. Translation axes are X, Y, Z with a resolution of about 1 µm. Tilting axes are U, V, W with about 1 arcsec resolution. The pivot point for the tilting axes can be defined as any point (coordinates R,S,T) within the X,Y,Z coordinate system. As default the vertex represents the pivot point for angular movements.

The velocities of the linear actuators are calculated and matched for linear path trajectories while moving from position A to position B. All movements are related to the center position defined by the **HREF** command.

Parameters:	X,Y,Z,U,V,W,R,S,T		
Format:	Float		
Value:	X,Y	= -5.0 ... +5.0	(mm)
	Z	= -12 ... +12	(mm)
	U,V,W	= -5.236e-2 ... +5.236-2 (rad), {3 deg}	
default:	Vertex position		
	R,S	= 0	(mm)
	T	= 55.85	(mm)

Example: **HMOV X1.0 Y-.5 Z10.0 U-1.745e-2**

This Example moves the HEXAPOD platform 1 mm in X,- 0.5 mm in Y and 10 mm in Z. Also a tilting of -1° around the U-axis and the vertex is carried out

HVEL {param}[value] Set or Report HEXAPOD Velocity

This command defines the path velocity for the HEXAPOD system. The velocity of a single axis depends on direction of motion and is evaluated from the coordinate transformation. The upper speed limit of about 1 mm/s is determined by the maximum speed of the DC-motors and the gear heads. For the rotation the velocity is determined by the angles U,V,W and the radius RTOP. If no parameter is defined the command reports the actual velocity parameter.

Parameter:	V
Format:	Float
Value:	0 .... 1.0 , default = 0.5 (mm/sec)
Example:	**HVEL V0.6**
	defines the path velocity of the HEXAPOD system to 0.6 mm/sec

HREF Initialize HEXAPOD to Reference Position

This command is used to move all six HEXAPOD actuators at the same time to its absolute center position. The incremental encoder counters for the DC-motors are reset in the center reference position.

The referencing starts with moving all HEXAPOS axis towards the center position with constant 0.5 mm/s axis velocity and following to the side with all reference signals low. Next the home position will be captured by an edge transition of the reference line from low to high. This is done with constant 0.1 mm/s axis velocity.

By this procedure the maximum time for referencing the HEXAPOD from any extreme position takes less than one minute. After all axis are referenced the commanded axis velocities are restored.

Example: **HREF** initializes the HEXAPOD

NOTE:

The **HREF** command must be executed if the system is powered up to ensure safe HEXAPOD operation. No other HEXAPOD motion commands will be accepted until **HREF** has been executed !

STOP {param}[value] STOP HEXAPOD OR SINGLE AXIS

This command stops (decelerated) the movement of the HEXAPOD or one or more motor axes.

Parameter: N

Format: Byte

Value: 0: stops HEXAPOD

1..8: stops single axis

default: N = 0

XPOS {param}[value] Set Auxiliary Motor Position

This command is used to control two additional DC-motors for axis 7 & 8 operation. Incremental encoder quadrature signals are required for position control.

n represents the motor axis number and P contains the target position in counts.

Parameters: n, P

Format: Integer

Values: n = 7,8

P= -2^29 - 1... +2^29 -1 (counts)

NOTE:

For some service purposes it might be useful to execute movements for each HEXAPOD actuator individually without the coordinate transformation. This results in all six degree of freedom movements.

Parameter: n, P

Format: Integer

Value: n = 1 ... 6

P=-64800...+64800 (counts), (13.5 x 4800 counts/ mm)

These options should only be used from experienced engineers while observing the mechanics.

XPAR {param}[value] Set Auxiliary Motor Motion Parameters

This command defines velocity and acceleration for the extra DC-motors with the axis numbers N which are used for axis 7 & 8 operation.

Parameter: N,V,A

Format: Float

Value: N= 7,8

default: V= 30.72 count/T
A= 0.1 counts/T/T

XPID {param}[value] Set Auxiliary Motor Control Parameters

This command defines the PID filter parameters and the integration limits for the extra DC-motors with axis N (SKY SHUTTER). These values are not reported.

Parameter: N,P,I,D,L

Format: Integer

Values: N= 7, 8
P= 100
I= 100
D= 10
L= 1000

STAT* {param}[value] Report System Status

This command reports internal states of the system. All informations are self explaining.

On the MPIC this command reports the MPIC or reflected HEXC status. With parameters N=10 .. 35 this command reports HEXC information by transferring this STAT command to the HEXC controller and receiving data via the downlink. The data are formatted to an ASCII string and transmitted to the host.

All status information about the HEXC are the same requested by the STAT command on the HEXC controller direcly. Due the limited transfer capacity on the downlink the informations are splitted off in several commands with different parameters on the MPIC.

Parameter: N

Format: Byte

Value: N=0: MPIC system status
N=1: HEXC system status
N=2: Voltages of the power supplys and amplifier outputs
N=10: HEXC system values
N=20: Commanded HEXAPOD position
N=21: Commanded pivot point
N=22: Computed leg position
N=23: Computed leg velocity
N=24: Commanded HEXAPOD velocity
N=30: All motor controller status

N=31: Real position of all axis
N=32: Reference readout of all axis
N=33: Current velocity of all axis
N=34: Current acceleration of all axis
N=35: Status flags of all axis

On the HEXC this command reports the system, HEXAPOD or all axis status.

Parameter: N

Format: Byte

Value: N=0: Shows HEXC system status
N=1: Shows HEXAPOD status
N=2: Shows all axis status
default N=0

HELP* {param}[value] HELP

This command generates a list of available commands. Only the controller specific commands are displayed. Additional on the HEXC controller a help level 1..3 can be set for more detailed information what's going on. A help level of zero stops all information output.

QUIT*	**STOP COMMUNICATION**

Sets help level on the HEXC to zero and stops communication with external terminal.

REST*	**RESTART**

Restart MPIC or HEXC analog power on. No hardware reset !.

SETF {param}[value] Set or Report Tilting Mirror Control Flags

This command defines the control flags of the TM-UNIT system. If no parameters are defined, the command reports the actual mirror control flags. The following parameters are used:

P (Piezo)	P1 or P0 sets all PZTs ON or OFF = Freeze last PZT- Voltage
S (Servo)**	S1 = PID closed loop on, S2 = PID closed loop and lead compensator on, S0 = open loop

C (Comp)	Enable/Disable momentum compensation. This defines whether the backwards directed PZTs will be activated or not.
A (Auto)	Enable/Disable self-executing motion commands sine- wave signal or chopping. See also commands **MSIN** and **MCHP**
X (Extern)	Enable/Disable external analog inputs to PZT amplifiers

Parameters:	P,S,C,A,X
Format:	Integer
Values:	P,C,A,X: 0=off, 1=on
	S :0 = PID off, 1= PID on, 2 = PID + Lead = on
Example:	SETF S1 C1 A1
	Enables the closed loop position PID- control and the momentum compensation. Also the chopping or sine- wave mode is enabled with the parameters defined with the MSIN or MCHP command.

Appendix A : System Specifications

HEXAPOD Specifications:

<u>Range of Travel (independent*):</u>	X/Y Motion	+/- 2 mm
	Z Motion	+/- 12 mm
	Angular Motion U/V	+/- 0.5 deg

* independent means motion commands can be executed within all of the above limits at any combination at the same time (HEXAPOD leg stroke <=13.5mm). without creating a geometry error.

<u>Range of Travel (dependent*):</u>	X/Y Motion	+/- 5 mm
	Z Motion	+- 12 mm
	Angular Motion U/V/W	+/- 3 deg

* dependent means if not all movement is needed for one or more degree of freedom more travel range is available for specific axes but a geometry error could be created if the requested total leg stroke exceeds +/- 13.5 mm.

Appendix B : Pin Assignment

Power- Extension Cable

2x LEMOSA- Connector FGA.3B.318.CYCD10ZR, red

PIN/Side A	Signal /Function		PIN/Side B
1 + 2	+15V / 3A	Motor	11+12
3 + 4	-15V / 3A	Motor	9+10
5 + 6	GND	Motor	7+8
7	+15V	Sensor	6
8	-15V	Sensor	5
9	GND	Sensor	4
10 + 11 + 12	+5V	Digital Part	1+2+3
14 + 15 + 17	GND	Digital Part	15+17+18
13 + 16		Cable check	13+16
18	NC		14

PZT- Extension Cable

2x LEMOSA- Connector FGG.3B.318.CYCD10ZN,black

PIN/Side A	Signal /Function	PIN/Side B
1	PZT 1+	12
2	PZT 1 Sense	11
3	PZT 2+	10
4	PZT 2 Sense	9
5	PZT 3+	8
6	PZT 3 Sense	7
7	PZT 4+	6
8	PZT 4 Sense	5
9	PZT 5+	4
10	PZT 5 Sense	3

11	PZT 6+	2
12	PZT 6 Sense	1
13	Cable check	13
14	PZT 1 GND	18
15	PZT 2 GND	17
16	Cable check	16
17	PZT 3 GND	15
18	GND SENSE	14

Serial Data Link (RS-422)

2x LEMOSA-Connector FGG.1B.310.CYCD72ZN, black

PIN/SideA	Signal /Function	PIN/SideB
1	reserved	
2	AGND	8
3	U-OUT	9
4	AGND	10
5	V-OUT	7
7	LINKIN B	3
8	LINKIN A	2
9	LINKOUT Z	5
10	LINKOUT Y	4