Instrument Adapter Subsystem Interface for the WIYN 3.5 Meter Telescope

Document number: WODC 01-19-03

Revised May 8, 1995, by S. Gott

PLEASE DISCARD PREVIOUS REVISIONS

Major changes since October 6, 1994:

1. Several redundant or un-needed commands have been eliminated, Others have been re-named.

2. The serial message format has been changed to eliminate the "address" byte, and to add an "axis number" byte. The axis number has been removed from all data fields.

3. The command and axis numbers have been re-assigned, and are now given in decimal.

4. Added commands & response for control of LVDT power supply.

5. Added "spare" axes.

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1. Scope

This document specifies the electrical interface and communications protocol for the Instrument Adapter Subsystem (IAS) Controller.

2. Configuration

2.1 General

The IAS provides functions (acquisition, guiding, etc.) required for observing on the WIYN port of the WIYN telescope. The IAS consists of an instrument mounting box with calibration sources, control electronics (hereafter referred to as the Controller), and cameras with separate controllers.

The instrument mounting box mounts on the WIYN port Nasmyth Instrument Rotator (NIR) and provides a rigid mounting surface for Science Instruments. The Controller controls the following components:

- Dark slide for blocking light coming into the IAS.
- Two Atmospheric dispersion corrector (ADC) rotating stages.
- Slide for moving the ADC in and out of the beam.
- Spectral calibration sources.
- One calibration filter wheel.
- Wavefront sensing CCD camera (WFS) on x-z stage.
- Filter wheel for the wavefront sensing camera (WFS).
- Slide for moving the calibration source and wavefront sensing camera mirrors into the beam.
- ICCD guide camera on x-y-z stage.
- Two filter wheels in front of guide camera (nd and color).
- ICCD focus camera on x-y-z stage.
- Two filter wheels in front of focus camera (nd and color).
- Pupil wheel in front of focus camera.

The host computer sends commands to the Controller by a serial link. The Controller sends responses to the host.

The wavefront sensing CCD camera (WFS) has its own controller that mounts outside the IAS box. The camera controller provides power, shutter timing, integration control and the clocking signals for the CCD. The Image Processing computer is connected to the camera controller with a serial link.

The intensified CCD cameras output standard RS170 that goes directly to the image processing electronics off the IAS. Camera gain is controlled by an analog voltage provided by a remote power supply and potentiometer, operated from the observatory control room.

Power supplies for the Controller are located outside the IAS.

2.2 Axis Numbers, Motor Types, Positions, and Step Sizes

Axis Description	Axis Number	Motor Type	No. Pos.	Step Size
Dark slide	1	dc	2	in/out
ADC slide	2	dc	2	in/out
ADC rotator stage A	3	step		0.1 degree / step
ADC rotator stage B	4	step		0.1 degree / step
Feed mirror slide	5	dc	2	in/out
Guide probe x stage	6	step		10 microns / step
Guide probe y stage	7	step		10 microns / step
Guide probe focus stage	8	step		12.7 microns / step
Guide probe filter wheel	9	step	3	20 steps / position
Guide probe color wheel	10	step	2	20 steps / position
Focus probe x stage	11	step		10 microns / step
Focus probe y stage	12	step		10 microns / step
Focus probe focus stage	13	step		12.7 microns / step
Focus probe filter wheel	14	step	3	20 steps / position
Focus probe color wheel	15	step	3	20 steps / position
Focus probe pupil wheel	16	step	4	15 steps / position
Calibration filter wheel	17	step	4	200 steps / position
WFS camera x stage	18	step		10 microns / step
WFS camera focus stage	19	step		10 microns / step
WFS camera filter wheel	20	step	4	200 steps / position
Spare slide	21	dc	2	in/out
Spare stage A	22	step		undetermined
Spare stage B	23	step		undetermined
Calibration lamps		none	none	
A/D Converter		none	none	
LVDT Power Supply		none	none	

3. Controller Interface

The command structure will follow the conventions adopted by UWCG. It provides for high level commands implemented in the host system, using the primitive commands provided by the Controller. The primitive commands will be available to the user for troubleshooting and special operations.

The Controller will accept position, velocity, and acceleration in units of motor steps. The conversion from position on the sky (RA, dec, paralactic angle) to Controller coordinates will be done by the host system. In addition, the host will apply corrections for field distortion and misalignments of the IAS stages.

The Controller will acknowledge all commands immediately, following with an additional "command completed" response for those commands that involve mechanical motion (see Response Formats).

3.1 Serial Interface

The serial interface voltage levels used for communication between the control system and the IAS Controller follow the EIA standard RS422 with twisted pairs dedicated to transmission and reception.

3.2 Communications Protocol

A serial communications protocol has been designed for the IAS. Each message consists of a series of binary-encoded, 8-bit bytes. The format is:

Byte	#Function
1&2	Starting field (3232h).
3	Axis.
4	Command.
5	Data Field Length, 0-255 bytes (not including CRC or stop byte).
6 to n	Data.
n+1	CRC Most Significant Byte(CRC16 for the divisor).
n+2	CRC Least Significant Byte.
n+3	End of Message (03h).

The axis byte specifies the axis number for commands and responses that apply to a particular axis. For messages that apply to all axes, or to no axis, the axis number is meaningless and should be ignored.

Multi-byte data values are sent low byte first.

The CRC 16 error checking is chosen to be the same as SDLC format.
It is the CCITT-CRC polynomial X16 + X12 + X5 + 1.
See Appendix C for an example of C code used to calculate the CRC.

3.3 General Commands

3.3.1 RESET ALL

Initiate a system reset which includes the following actions:
Stop all motion immediately.
Turn off calibration lamps.
Reset all motion parameters to default values.
Command buffer is cleared and initialized.

Command: 0
Data field length: 0

3.3.2 HOME ALL

Send all axes home.

Command: 1
Data field length: 0

3.3.3 IMMEDIATE STOP ALL

Immediately stop motion of all axes.
WARNING: Position count(s) could be lost.

Command: 2
Data field length: 0

3.3.4 SEND CONTROLLER STATUS

Send a full controller status report to the host.

Command: 3
Data field length: 0

3.3.5 RESET AXIS

Reset the specified axis, and set all previously programmed parameters and settings to their default values.

Command: 10
Data field length: 0

3.3.6 HOME AXIS

Move to home position. Position counter is reset to zero on completion.

Command: 11
Data field length: 0

3.3.7 STOP AXIS

Decelerate the specified axis to a controlled stop.

Command: 12
Data field length: 0

3.3.8 SEND AXIS STATUS

Send Axis Status to the host.

Command: 13
Data field length: 0

3.4 Stage Commands

3.4.1 MOVE STAGE ABSOLUTE

Move the specified stage to the requested absolute position.
This command will fail if the absolute position has not been
defined by finding "home", or by a SET STAGE POSITION command.
This command may be used to modify the target position while
the stage is moving.

Command: 20
Data field length: 4 bytes
Data byte 1-4: Absolute position in steps from home
(signed 32 bit integer).

3.4.2 MOVE STAGE RELATIVE

Move the specified stepper motor by the requested distance.
This command may be used to modify the target position while

the stage is moving.

Command: 21
Data field length: 4 bytes
Data byte 1-4: Relative distance in steps from current position (signed 32 bit integer).

3.4.3 SET STAGE POSITION

Set the absolute position counter to the specified value.

Command: 22
Data field length: 4 bytes
Data byte 1-4: Position in steps (signed 32 bit integer).

3.4.4 SET STAGE VELOCITY

Set the maximum velocity in steps/second for the specified stage. This command can be used to modify the profile while motion is in progress.

Command: 23
Data field length: 4 bytes
Data byte 1-4: Maximum velocity in steps/sec (unsigned).

3.4.5 SET STAGE ACCELERATION

Set the acceleration/deceleration rates in steps per second^2 for the specified stage. This command can be used to modify the profile while motion is in progress.

Command: 24
Data field length: 5 bytes
Data byte 1-4: Acceleration in steps/sec/sec (unsigned).

3.4.6 SEND STAGE POSITION AND VELOCITY

Send Current Position and Velocity of the specified axis to the host.

Command: 25
Data field length: 0

3.5 Filter Commands

3.5.1 MOVE FILTER

Move the specified filter wheel to the requested position.
This command will fail if the absolute position has not been defined by finding the "home" position.
This command may be used to modify the target position while the filter wheel is moving.

Command:	30
Data field length:	1 byte
Data byte 1:	Filter position.

3.5.2 SEND FILTER POSITION

Send the position of the specified filter to the host.

Command:	31
Data field length:	0

3.6 Slide Commands

3.6.1 MOVE SLIDE

Move the specified slide in or out of the beam.
This command may be used to modify the target position while the slide is moving.

Command:	40
Data field length:	1 byte
Data byte 1:	Slide in/out of beam. (1=in, 0=out)

3.6.2 SEND SLIDE STATUS

Send the status of the specified slide to the host.

Command:	41
Data field length:	0

3.7 Calibration Lamp Commands

3.7.1 SET CALIBRATION LAMP

Turn calibration lamps on/off. (1=on, 0=off)
Calibration lamps do not have an axis number.

Command:	50
Data field length:	1 byte
Data byte 1:	Lamps on or off bit field:
	Bit 0-7 => Lamp 1-8.

3.7.2 SEND CALIBRATION LAMP STATUS

Send the states of the calibration lamps to the host.

Command:	51
Data field length:	0

3.8 Voltage Commands

3.8.1 SEND VOLTAGE

Send the voltage of the specified A/D channel.
The A/D channels do not have an axis number.

Command:	60
Data field length:	1 byte
Data byte 1:	A/D multiplexer channel number.

3.8.2 SET POWER

Set the state of the power supply on/off control.
The power supply does not have an axis number.

Command:	61
Data field length:	1 byte
Data byte 1:	Power supply on/off bit field.
Bit 0:	LVDT power. (1=on, 0=off)
Bit 1 - 7:	Not used. Set to 0.

3.8.3 SEND POWER STATUS

Send the status of the power supply to the host.
The power supply does not have an axis number.

Command:	62
Data field length:	0

3.9 Response Formats

The general format for a response is:

Command:	Echoes issued command.
Axis:	Echoes axis number command was issued to.
Data field length:	3 bytes for commands without telemetry, 3+n bytes for commands with telemetry.
Data byte 1:	ACK Bitfield defined by UWCG is reproduced here. (1=true, 0= not true)
Bit 0 - 4:	Not used.
Bit 5:	Error detected.
Bit 6:	Command complete.
Bit 7:	New command.
Data byte 2:	Error code. Least significant byte.
Data byte 3:	Error code. Most significant byte.
Data byte 4 - n:	Data is returned in bytes 4-n as defined in the following sections.

3.9.1 Controller Status

Content:	Status of All Axes.
Command:	SEND CONTROLLER STATUS
Data Field Length:	84 bytes
Data byte 1:	ACK Bitfield.
Data byte 2 - 3:	Error code.
Data byte 4 - 6:	
Bit 0 - 21:	Axes 1-20 Axis ready.
Data byte 7 - 9:	
Bit 0 - 21:	Axes 1-20 Axis Look-At-Me.
Data byte 10 - 11:	
Bit 0:	Dark slide inserted (axis 1).
Bit 1:	ADC slide inserted (axis 2).
Bit 2:	Feed mirror slide inserted (axis 5).
Bit 3:	Spare slide inserted (axis 21).
Bit 4:	All calibration lamps off.
Bit 5:	Task overflow.
Bit 6:	Not used.
Bit 7:	Not used.
Bit 8:	LVDT power supply on.
Bit 9:	+5 VDC ok.
Bit 10:	+12 VDC ok.
Bit 11:	-12 VDC ok.
Bit 12:	+24 VDC ok.
Bit 13 - 15:	Not used.

Data byte 12 - 13:	software version number = 1 (to be changed whenever this message format changes)		
Data byte 14 - 15:	A/D voltage, chan 0		
Data byte 16 - 17:	A/D voltage, chan 1		
Data byte 18 - 19:	A/D voltage, chan 2		
Data byte 20 - 21:	A/D voltage, chan 3		
Data byte 22 - 23:	A/D voltage, chan 4		
Data byte 24 - 25:	A/D voltage, chan 5		
Data byte 26 - 27:	A/D voltage, chan 6		
Data byte 28 - 29:	A/D voltage, chan 7		
Data byte 30 - 33:	position,	axis 3	ADC rotator stage A
Data byte 34 - 37:	position,	axis 4	Adc rotator stage B
Data byte 38 - 41:	position,	axis 6	Guide probe x stage
Data byte 42 - 45:	position,	axis 7	Guide probe y stage
Data byte 46 - 49:	position,	axis 8	Guide probe focus stage
Data byte 50:	wheel pos,	axis 9	Guide probe filter wheel
Data byte 51:	wheel pos,	axis 10	Guide probe color wheel
Data byte 52 - 55:	position,	axis 11	Focus probe x stage
Data byte 56 - 59:	position,	axis 12	Focus probe y stage
Data byte 60 - 63:	position,	axis 13	Focus probe focus stage
Data byte 64:	wheel pos,	axis 14	Focus probe filter wheel
Data byte 65:	wheel pos,	axis 15	Focus probe color wheel
Data byte 66:	wheel pos,	axis 16	Focus probe pupil wheel
Data byte 67:	wheel pos,	axis 17	Calib. filter wheel
Data byte 68 - 71:	position,	axis 18	WFS camera x stage
Data byte 72 - 75:	position,	axis 19	WFS camera focus stage
Data byte 76:	wheel pos,	axis 20	WFS camera filter wheel
Data byte 77 - 80:	position,	axis 22	Spare stage A
Data byte 81 - 84:	position,	axis 23	Spare stage B

3.9.2 Axis Status.

Content:	Axis status.
Command:	SEND AXIS STATUS
Data field length:	5 bytes
Data byte 1:	ACK Bitfield.
Data byte 2 & 3:	Error code.
Data byte 4 & 5:	
Bit 0:	On position; set while programmed position is equal to current position.
Bit 1:	On velocity; set while programmed velocity

is equal to current velocity.
Bit 2: Acceleration in progress; set while motor is accelerating.
Bit 3: Deceleration in progress; set while motor is decelerating.
Bit 4: In motion; set while motor is moving.
Bit 5: Not used.
Bit 6: Not used.
Bit 7: External input 1; level of limit switch 1 status.
Bit 8: External input 2; level of limit switch 2 status.
Bit 9: External input 3; level of limit switch 3 status.
Bit 10: Disable line; level of disable input.
Bit 11: Direction out; level of direction output.
Bit 12: Step out; level of step output.
Bit 13: Encoder index; level of encoder index or Z input.
Bit 14: Encoder direction in; level of encode direction on closed loop, same as direction out on open loop.
Bit 15: Encoder step in; level of encoder step pulse on closed loop, invalid on open loop.

3.9.3 Stage Position and Velocity.

Content: Current position and velocity of the specified stage.
Command: SEND STAGE POSITION AND VELOCITY
Data field length: 11 bytes
Data byte 1: ACK Bitfield.
Data byte 2 & 3: Error code.
Data byte 4 - 7: Current position in steps.
Data byte 8 - 11: Current velocity in steps/second.

3.9.4 Filter Position.

Content: Position of the specified filter wheel.
Command: SEND FILTER POSITION
Data field length: 4 bytes
Data byte 1: ACK Bitfield.
Data byte 2-3: Error code.
Data byte 4: Filter position.

3.9.5 Slide Status.

Content: Status of the specified slide.
Command: SEND SLIDE STATUS
Data field length: 4 bytes
Data byte 1: ACK Bitfield.
Data byte 2 - 3: Error code.

Data byte 4:
- Bit 0: Out.
- Bit 1: In.
- Bit 2: Moving.
- Bit 3: Direction.
- Bit 4: Position Undetermined.
- Bit 5 - 7: Not used.

3.9.6 Calibration Lamp Status.

Content: Calibration lamp states.
Command: SEND CALIBRATION LAMP STATUS
Data field length: 4 bytes
Data byte 1: ACK Bitfield.
Data byte 2 - 3: Error code.
Data byte 4: Lamp state bitfield.
- Bit 0 - 7: Lamp 1-8. (1=on, 0=off)

3.9.7 A/D Voltage.

Content: Digitized value of the specified channel input. This raw, 12-bit number is sent as read from the A/D converter. Conversion to volts or other units will depend on the configuration of each channel.
Command: SEND VOLTAGE
Data field length: 6 bytes
Data byte 1: ACK Bitfield.
Data byte 2 - 3: Error code.
Data byte 4: A/D Channel number.
Data byte 5 - 6:
- Bit 0 - 11: 12 bit data from A/D converter.
- Bit 12 - 15: Not used, set to 0.

3.9.8 Power Supply Status.

Content: Power supply states.
Command: SEND POWER STATUS
Data field length: 4 bytes
Data byte 1: ACK Bitfield.
Data byte 2 - 3: Error code.
Data byte 4: Power supply state bitfield.
- Bit 0: LVDT power supply on.
- Bit 1: +5 VDC ok.
- Bit 2: +12 VDC ok.
- Bit 3: -12 VDC ok.
- Bit 4: +24 VDC ok.

Bit 5 - 7: Not used, set to 0.

Appendix A Commands vs. Allowed Axis Numbers

Command	Command	Allowed Axes
RESET ALL	0	NONE
HOME ALL	1	NONE
IMMEDIATE STOP ALL	2	NONE
SEND CONTROLLER STATUS	3	NONE
RESET AXIS	10	ALL
HOME AXIS	11	ALL
STOP AXIS	12	ALL
SEND AXIS STATUS	13	ALL
MOVE STAGE ABSOLUTE	20	STAGES
MOVE STAGE RELATIVE	21	STAGES
SET STAGE POSITION	22	STAGES
SET STAGE VELOCITY	23	STAGES
SET STAGE ACCELERATION	24	STAGES
SEND STAGE POSITION AND VELOCITY	25	STAGES
MOVE FILTER	30	WHEELS
SEND FILTER POSITION	31	WHEELS
MOVE SLIDE	40	SLIDES
SEND SLIDE STATUS	41	SLIDES
SET CALIBRATION LAMP	50	NONE
SEND CALIBRATION LAMP STATUS	51	NONE
SEND VOLTAGE	60	NONE
SET POWER	61	NONE
SEND POWER STATUS	62	NONE

Allowed Axes Definitions:

NONE	=
ALL	= 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23
STAGES	= 3,4, 6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 22,23
WHEELS	= 9,10, 14,15,16,17, 20
SLIDES	= 1,2, 5 21

NOTE: Since filter wheels are driven by stepper motors, "stage" commands may be applied to wheels also.

Appendix B Axis Numbers vs. Allowed Commands

Axis	Axis Description	Allowed Commands
1	Dark slide	SLIDE_CMDS
2	Adc slide	SLIDE_CMDS
3	Adc rotator stage A	STAGE_CMDS
4	Adc rotator stage B	STAGE_CMDS
5	Feed mirror slide	SLIDE_CMDS
6	Guide probe x stage	STAGE_CMDS
7	Guide probe y stage	STAGE_CMDS
8	Guide probe focus stage	STAGE_CMDS
9	Guide probe filter wheel	WHEEL_CMDS
10	Guide probe color wheel	WHEEL_CMDS
11	Focus probe x stage	STAGE_CMDS
12	Focus probe y stage	STAGE_CMDS
13	Focus probe focus stage	STAGE_CMDS
14	Focus probe filter wheel	WHEEL_CMDS
15	Focus probe color wheel	WHEEL_CMDS
16	Focus probe pupil wheel	WHEEL_CMDS
17	Calib. filter wheel	WHEEL_CMDS
18	WFS camera x stage	STAGE_CMDS
19	WFS camera focus stage	STAGE_CMDS
20	WFS filter wheel	WHEEL_CMDS
21	Spare slide	SLIDE_CMDS
22	Spare stage A	STAGE_CMDS
23	Spare stage B	STAGE_CMDS

Allowed Commands Definitions:

STAGE_CMDS = 10,11,12,13,20,21,22,23,24,25,
WHEEL_CMDS = 10,11,12,13,20,21,22,23,24,25,30,31
SLIDE_CMDS = 10,11,12,13, 40,41

NOTE: Since filter wheels are driven by stepper motors, "stage" commands may be applied to wheels also.

Appendix C Function for CRC Calculation

This C function is used to calculate the 16-bit CRC value to be included in outgoing messages, and to calculate a value for comparison with the CRC included in incoming messages.

```
/*  Calculate CRC on contents of <buffer>, using the CCITT-CRC
    polynomial X16+X12+X5+1.  CRC is calculated on all bytes in the
    message except the two CRC bytes and the end-of-message byte.

    Adapted from "ocsCalcCrc()" by Kevin Schlitter of the
    University of Wisconsin.

    Revised to incorporate Jeff Percival's suggestions:

        1. CRC should include the first two bytes in the message.

        2. The line:        crc ^= (unsigned int)buffer[i]

           should be:       crc ^= (int)buffer[i] & 0xff;
*/

#define LEN     4       /* location of "Data Field Length" byte */

int calcCRC(BYTE* buffer)
{
    int i, end, crc;

    end = 5 + buffer[LEN];
    crc = 0;

    for (i = 0; i < end; ++i)

        crc ^= (int)buffer[i] & 0xff;

    crc ^= ((crc << 5) & 0xffff) ^ ((crc << 12) & 0xffff);

    return(crc);
}
```

Appendix D Error Codes

Each response message from the IAS will include one of these code numbers in the 16-bit error code field.
Additional codes will be added later.

Name	Code No.	Interpretation
NO_ERROR	0	everything is okey-dokey
INTERNAL_ERROR	1	controller internal error
CRC_ERROR	2	command message CRC was wrong
MSG_ERROR	3	incorrect command message format
AXIS_ERROR	4	command is not allowed for this axis
CMD_ERROR	5	command is not implemented
FAIL_ERROR	6	command execution failed
CHAN_ERROR	7	bad a/d converter channel number
RANGE_ERROR	8	commanded value out of range
MOVING_ERROR	9	command rejected because axis is moving
LIMIT_ERROR	10	axis hit a limit switch
TIMEOUT_ERROR	11	axis exceeded its time limit
STALL_ERROR	12	motor stall detected
NOHOME_ERROR	13	can't move absolute - home position unknown

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