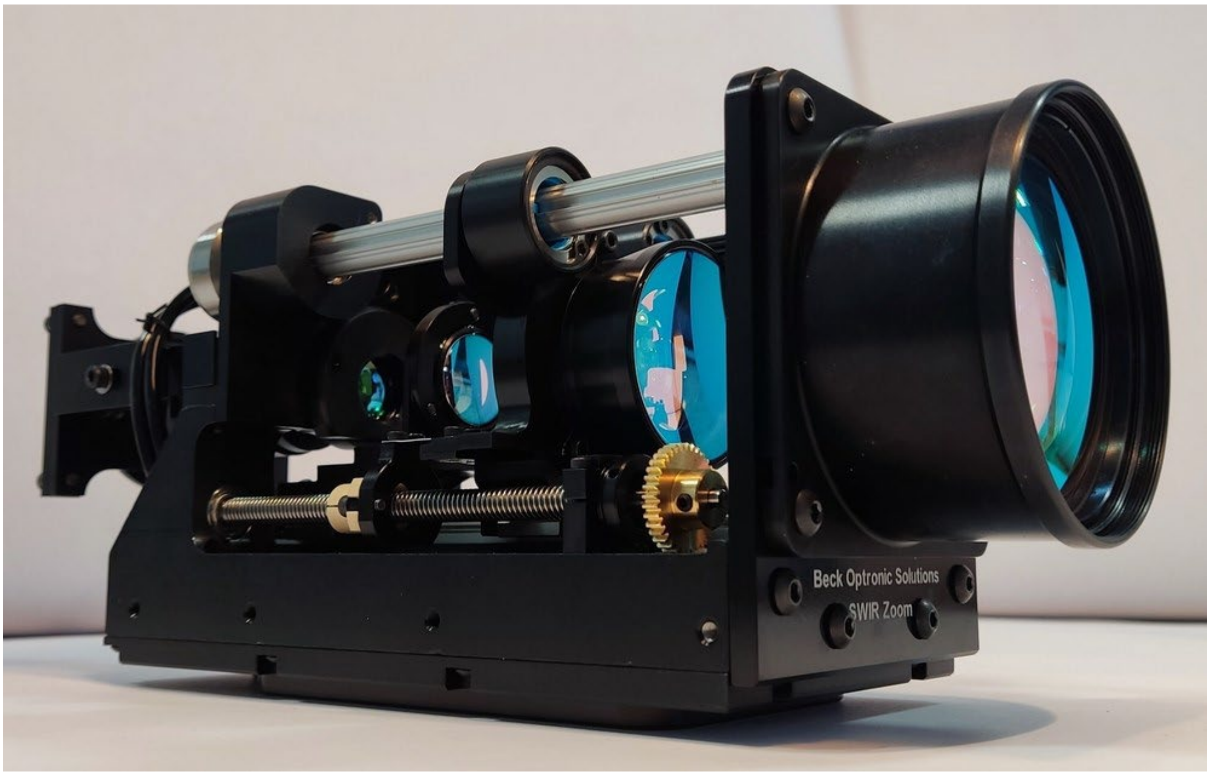
Introduction

Beck Optronic Solutions offers a range of ruggedised, high-performance zoom lenses based on a common chassis and that share the same control electronics. Applications include, but are not limited to, long range surveillance, border security and remote weapon stations.

These lenses are designed to operate over the 700-1700nm SWIR waveband of the latest InGaAs detectors, using aspheric lens design and materials optimised for this spectrum. They are fully automated for remote control, are built to full Mil-SPEC, and can be tailored to meet specific customer requirements.



This document presents the specifications, quick start guide, electrical interface and commands for manual control of the Beck Optronics Solutions (BOS) SWIR zoom lens.

Contents

1 SPECIFICATIONS

Focal length	20-200mm	26.5-265mm	33-330mm	53-530mm
F/#	F/4	F/5.3	F/6.6	F10.6
Image size (diagonal)	12.4mm	16.4mm	20.5mm	33mm
Focus range	Range 10m to infinity			
Zoom speed	≤5s			
Boresight retention	≤± 0.1mrad			
Operational temperature range	-25° C to +70°*C*			
Voltage input	12VDC nominal (7-15VDC)			
Power draw	0.5A maximum			
Vibration	Tracked vehicle, MIL-STD-810G, method 514.6			
Shock	Transportation: 3 shocks in each direction, 25g6ms			
Dimensions to image plane (mm)	230.7×108.7×85.2	249.6×108.7×85.2	273.8×108.7×85.2mm	326.7×108.7×85.2
Camera mount	C-mount or customer specified.			
Control interface	UART TTL, RS422 and RS485			

2 QUICK START GUIDE

To get started, the following items will be required:

1. Zoom lens with interface connector cable.
2. Zoom Lens Control Panel Lite software (provided on USB memory stick).
3. 12VDC power supply.
4. Camera with live image monitor.
5. Windows 64bit PC.
6. USB to serial converter (TTL, RS422 or RS485), or our connector interface board with built-in USB-TTL converter (sold separately).

Items 1-2 are provided by Beck and included in the box (see Fig.2). The software provides an onscreen control panel to operate the lens from a 64bit Windows host PC over any of the supported communication interfaces.

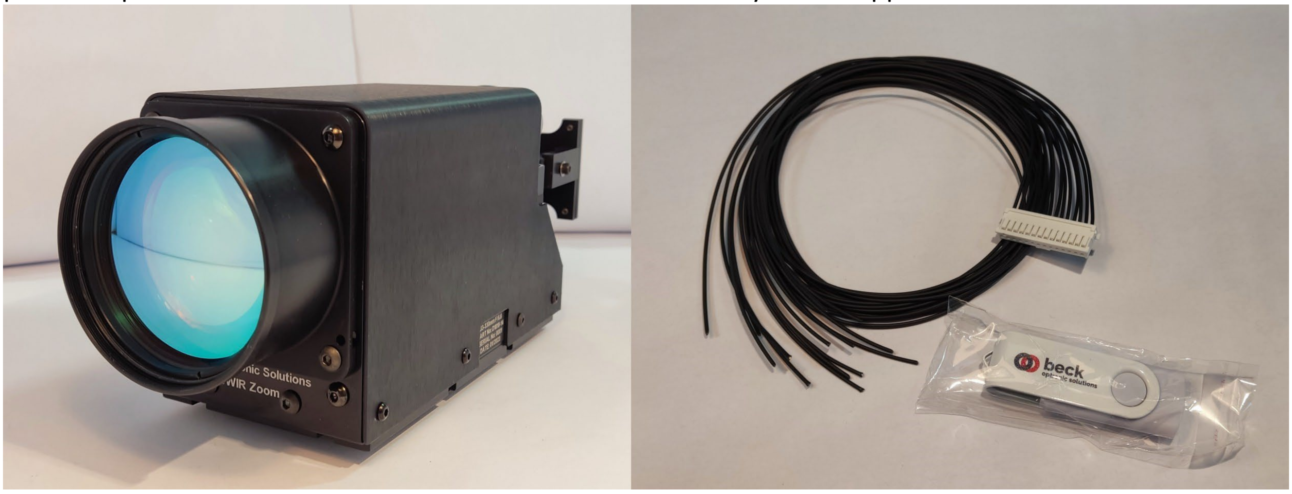


Figure 2: (left) SWIR Zoom lens, and (right) mating cable assembly and USB memory stick.

2.1 Connections

All connections to zoom lens are serviced by a single connector at the rear of the lens assembly(see Fig.3). That is a Molex MicroClasp 55935-1410. Its mating connector is 51382-1400.

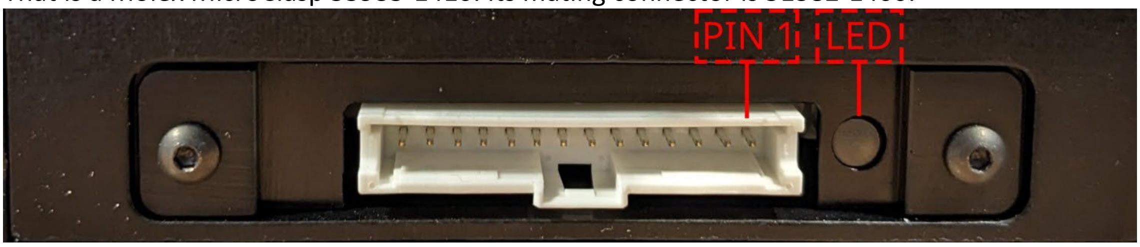


Figure 3: Connector and LED indicator on rear of lens. If LED shows a steady green = power on, blinks every 3s = heartbeat or more frequently = communications activity.

2.2 Pinout

A simplified pinout table is provided below. For more detail (e.g. tolerances, recommended operating parameters, etc.) see section 4.1.2.2.

Pin	Signal	Description
1	VDD	12VDC input.
2	GND	Ground.
3	RX	TTL serial receive data form system to lens.
4	TX	TTL serial transmit data form lens to system.
5	GND	Signal ground.
6	+RX	RS422 or 4-wire RS485 high-level serial receive data*.

7	-RX	RS422 or 4-wire RS485 low-level serial receive data*.
8	+TX	RS422, 4-wire RS485 high-level serial transmit data or RS485 2-wire positive data line (‘B’)*.
9	-TX	RS422, 4-wire RS495 low-level serial transmit data or RS485 2-wire negative data line (‘A’)*.
10	GND	Signal Ground.
11	+TC	Thermocouple positive terminal**.
12	-TC	Thermocouple negative terminal**.
13	+Heater	Heater positive terminal**.
14	-Heater	Heater negative terminal**.

* RS422 configured by default out-of-the-box. For 4- or 2-wire RS485, see section 4.1.4.2.

** Thermocouple and heater pass-through if fitted.

2.3 Connector Breakout PCB

A Connector Breakout PCB with mating cable to lens can be provided to aid in bench testing and rapid development (see Fig.4).

Figure 4: Connector interface board with mating cable to lens.

The lens can be powered through the Connector Breakout PCB with a standard 12V DC power adapter. The included FTDI USB to UART-TTL adapter IC and micro-USB socket provide a direct connection to PC. All other communication interfaces are broken out to terminal blocks. For more information, see section REFERENCE

2.4 Getting Started

1. Connect 12V DC power supply to lens according to pinout in section 3.2, or through Connector Breakout PCB and turn it on. The LED on the lens should show a steady green.

2. Through any one of the communication interfaces, connect to PC using a serial adapter.

3. Run ZoomLensControlPanelLite.exe.

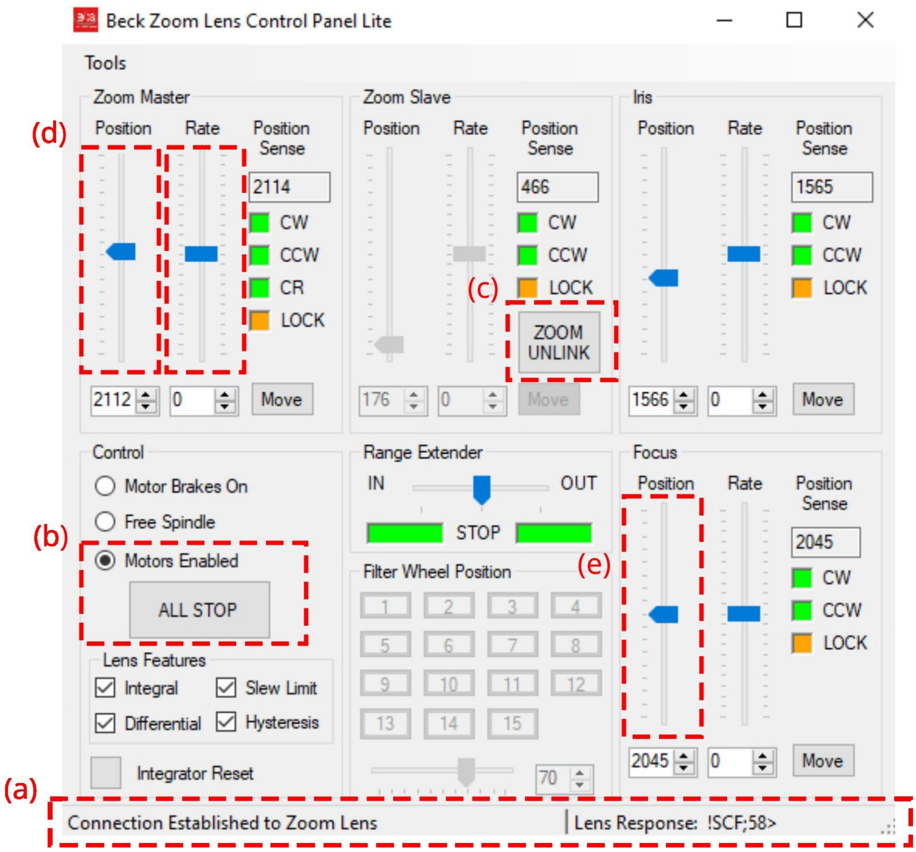


Figure 5: Screenshot of Control Panel software to operate zoom lens. Highlighted areas draw attention to a zoom lens communicating with the panel and driven to ∼50% of travel range of master optical group.

4. Serial port should be auto detected.

5. If lens detected, ‘Connection Established to Zoom Lens’ and ASCII messages should appear at the bottom of window (see highlight area *a* in Fig.6).

6. Click on ’Motors Enabled’ (see highlight area *b* in Fig.6).

7. Ensure ’ZOOM UNLINK’ is displayed. This indicates the zoom groups are currently LINKED together, and the ’Zoom Slave’ slider should be greyed out (see highlight area *c* in Fig.6).

   To zoom maximally out i.e. wide field of view and shortest focal length, move ’Zoom Master’ slider all the way up (see highlight area *d* in Fig.6).

   To zoom maximally in i.e. narrow field of view and longest focal length, move ’Zoom Master’ slider all the way down.

   Speed of zoom travel can be varied with ‘Zoom Master’ ’Rate’ slider.

8. Set camera to back focus of lens according to section 3.5.

9. Set camera to boresight axis of lens according to section 3.6.

10. The system is now setup.

11. For demonstration, an auto scroll facility is provided to cycle continuously through the full zoom travel range. The menu for this function is available under ’Tools’ and ’Auto Scroll’.

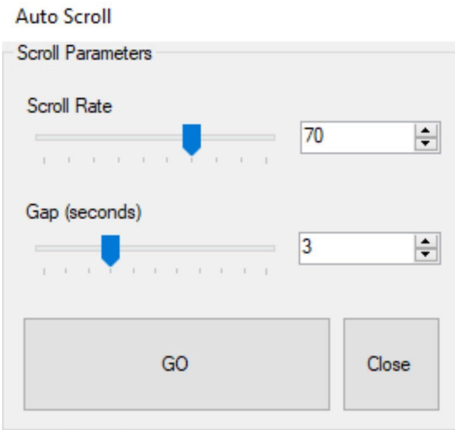


Figure 6: Screenshot of Auto Scroll menu to continuously cycle over full zoom travel range.

2.5 Back Focus

A zoom lens is required to stay in focus throughout its travel range. This is only possible at the nominal (design) back focus position. The method below details how to put camera sensor at the correct back focus position.

1. Drive zoom lens to wide field of view i.e. zoom out.
2. Mechanically adjust sensor position to focus on target.
3. Drive zoom lens to narrow field of view i.e. zoom in.
4. Adjust focus (via software slider) of zoom lens to focus on target (see highlight area *e* in Fig.6).
5. Drive zoom lens back to wide field of view and confirm target is still in focus (changing focus has little effect at this end of the zoom range).

2.6 Boresight

A zoom lens is required to keep an object at the centre of field of view throughout its travel range. This defines the optical axis or boresight of lens. For this to coincide with centre of image from camera sensor, the sensor must be positioned or “shuffled” to the axis of lens. The method below details how to align the camera sensor to boresight axis of Zoom Lens.

1. Drive Zoom Lens to wide field of view (zoom out).
2. Point Zoom Lens such that target is centred on camera image.
3. Drive Zoom Lens to narrow field of view (zoom out) and note both vertical and horizontal components of the boresight error (displacement along axis of sensor).
4. Fine adjust pointing of Zoom Lens to centre target on camera image.
5. Drive Zoom Lens to wide field of view (zoom out) and shuffle camera to centre the target.
6. Return to narrow field of view (zoom out) and remeasure boresight errors.
7. Iterate over steps 4-7 until boresight error (when zoomed in) is within acceptable limits.

3 ELECTRICAL INTERFACE

3.1 Panel Layout

The SWIR Zoom Lens Control PCB has only two externally facing parts accessible through the lens flange: D1, an activity indicator LED and CN1, a monolithic system connector combining power, data and ancillary connections.

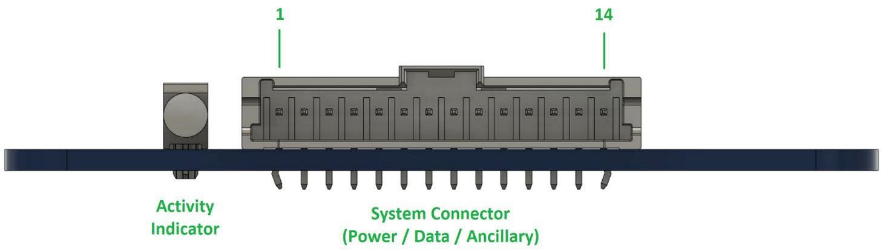


Figure 7: Layout of back panel on zoom lens.

Connector	Part Number	Description
D1	Dialight 515-1049-F	3.6mm diameter LED light pipe indicating power status and communications activity. Can be disabled in software.
CN1	Molex "Micro-clasp" 55935-1410	14-way Right Angle 2.0mm pitch wire-to-board connector, 2.5A max per contact*, with locking latch.

(* using 22AWG wiring. We recommend using a minimum of 24AWG or thicker for 2.0A current capacity on power and ancillary pins and minimum 28AWG for data pins).

3.1.1 Activity Indicator

The activity indicator LED lights green when the unit is powered on. If the lens is receiving commands on either of its two communication ports, the indicator will blink rapidly. If there is no communication activity, the indicator will blink once approximately every 3sec to indicate that the lens is ready and listening for commands.

If the lens is required not to have any illumination for system optical or covert requirements, the indicator can be disabled by a simple software command (see section 4.1.4.4). The configuration is retained in the Lens non-volatile memory, so the command only needs to be issued once.

3.1.2 System Connector

3.1.2.1 Mating Part

The mating part number for the system connector is Molex# 51382-1400. Use crimp terminals Molex# 56134 or pre-crimped leads 79758-100X.

3.1.2.2 Pinout

Pin	Signal	Description
1	+VDC	Nominal +12V DC powers lens controller through regulated internal supplies and lens motors direct. Supported V(in) range = +7.0V to +16.0V DC.
2	GND	Signal Ground.
3	RX	TTL Serial Receive data direction from system to lens. Tolerant to +5V. Filtered and ESD protected to +/- 30kV.
4	TX	TTL Serial Transmit data direction from lens to system. Outputs at 3.3V. Filtered and ESD protected to +/- 30kV.
5	GND	Signal Ground.
6	RS422 RX+	RS422 / 4-wire RS485 Receive data (positive) direction from system to lens. In 2-wire mode, this pin is unused. Filtered and ESD protected to +/30kV.
7	RS422 RX-	RS422 / 4-wire RS485 Receive data (negative) direction from system to lens. In 2-wire mode, this pin is unused. Filtered and ESD protected to +/30kV.
8	RS422 TX+ & RS485 A	RS422 / 4-wire RS485 Transmit data (positive) direction from lens to system. Bidirectional signal (positive) in 2-wire RS485. Filtered and ESD protected to +/- 30kV.
9	RS422 TX- & RS485 B	RS422 / 4-wire RS485 Transmit data (negative) direction from lens to system. Bidirectional signal (negative) in 2-wire RS485. Filtered and ESD protected to +/- 30kV.
10	GND	Signal Ground.
11	Thermocouple +	Positive signal for lens thermocouple (if fitted).
12	Thermocouple -	Negative signal for lens thermocouple (if fitted).
13	Heater +	Positive signal for lens heater element (if fitted).
14	Heater -	Negative signal for lens heater element (if fitted).

3.1.3 DC Electrical Characteristics

3.1.3.1 Absolute Maximum Ratings

Do not exceed any of these ratings. Doing so may cause permanent damage to the device.

	Min	Max	Unit
Supply Voltage (+VDC to GND)		19.0	V
RX pin Input Voltage	-0.5	6.5	V
RX pin Input Clamp Current		-50	mA
RS422/RS485 interface pins	-60	+60	V
Operating Ambient Temperature	-40	+65	°C
Storage Temperature	-40	+125	°C

3.1.4 Recommended Operating Conditions

	Min	Nom	Max	Unit
Power Supply				
Supply Voltage	7.0	12.0	16.0	V
Quiescent Supply Current (all motors braked)		120		mA
Supply Current (all motors running)		250	1000	mA
TTL UART Interface				
RX pin Input Voltage	0		5.5	V
Tx pin Output Voltage	0		3.3	V
Tx pin Output Current			7	mA
RX High-Level Input Voltage	1.39			V
RX Low-Level Input Voltage	0.65			V
TX High-Level Output Voltage	2.8			V
TX Low-Level Output Voltage			0.21	V
RX Input Current			1.0	uA
RX Input Capacitance	2		10	pF
RX Input Transition Rise/Fall rate			20	ns/V
Data Rate			3.125	Mbps
RS422/RS485 Interface				
Receiver input current	-100		125	uA
Receiver input resistance (termination off)			112	kW
Receiver common mode voltage	-25		+25	V

Differential input signal threshold	200			mV
Differential Driver output voltage	1.5		3.3	V
Common-mode Output Voltage			3	V
Maximum driver short circuit current		150	250	mA
Maximum data rate			250*	kbps
Driver differential skew			500*	ns
Driver rise/fall time	500*	800	1200	ns

(* performance limited for better EMC immunity. A high speed option up to 20Mbps can be configured on request).

3.1.4.1 Communications Interfaces

The lens supports two serial communications interfaces which may be used simultaneously, if required, for example to control the lens from a COTS Pelco-D controller on one port while reporting lens status to an attached system on the other.

Port “A” uses 3.3V TTL signalling levels (5V rx tolerant) and is suitable for close-coupled connection to intra-system components or as an intermediate to another signalling standard, e.g. USB.

3.1.4.2 Duplex / Termination options

The default configuration, as supplied, is 4-wire full-duplex with 120Ω termination enabled. This is compatible with the RS422 signalling standard.

The lens is also compatible with other bus topologies, for instance, 4-wire multi-point RS485 in which the bus termination is fitted externally, and 2-wire half-duplex RS485.

To facilitate the change in bus connection, there are two miniature DIP switches fitted to the lens PCB, just behind the MicroClasp system connector CN1.

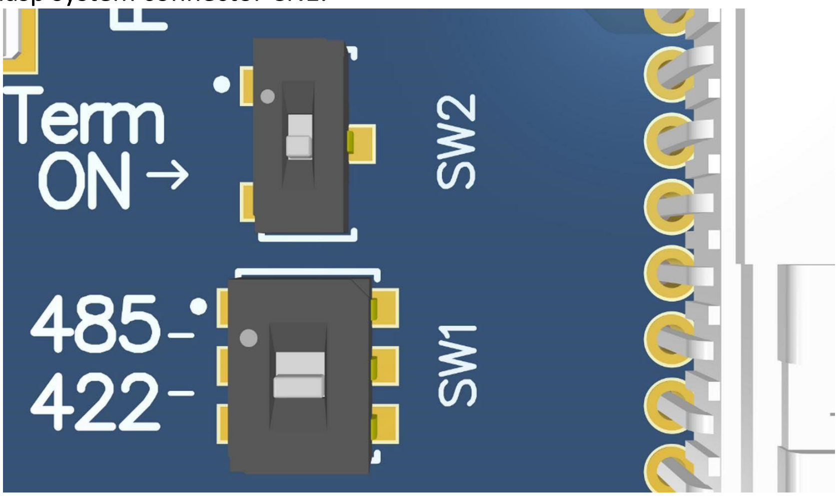


Figure 8: RS422 & RS485 signal configuration setup dip switches.

The two switches SW1 and SW2 are shown above in their default settings.

SW1: If the switch is set to “422”, commands are received on the Rx+/Rx- pair (pins 6-7) and transmitted on the Tx+/Tx- pair (pins 8-9). If set to “485”, commands are both received and transmitted on the same pair

A/B (pins 6-7). (NOTE: depending on the RS485 network biasing, it may also be necessary to configure the software for 2-wire/4-wire mode, see section 4.1.4.4 for details on the "WI" system command).

SW2: If the switch is set in the lower position, the 120Ω termination resistor is placed across the Rx+/Rx- (4 wire) or A/B (2-wire) pair. If in the upper position, the termination resistor is bypassed. In summary, you can normally use these recommended settings:

	SW1	SW2
4-wire RS422	DOWN	DOWN
4-wire RS485	DOWN	UP
2-wire RS485	UP	UP

3.1.4.3 Serial Configuration

Both port A and port B are completely configurable for serial parameters. They support the following options:

Parameter	Range	Default
Baud Rate (bps)	120 – 3,125,000*	38,400
Data Bits	7, 8**	8
Parity	Odd, Even, None	None
Stop Bits	1-2	1

* RS422/485 limited to 250kbps by driver. ** Pelco-D requires 8-bits.

3.1.4.4 1.6 Configuration Commands

The following ASCII commands may be used to change the configuration of the lens and its communications interfaces:

Command	Description	Write Example	Read Example
LE	LED Enable / Disable	<LE0;**> - disable LED <LE1;**> - enable LED	?LE;**>
BA	Set Baud Rate port A (TTL). Value should be within the supported range. The baud rate generator has a resolution of 320ns so any values that are not an integer multiple will have a small quantizing error.	<BA115200;**> - Set TTL baud rate to 115200bps	?BA;**>
BB	Set Baud Rate port B (RS422/RS485)	<BB9600;**> - Set RS422/RS485 baud rate to 9600bps.	?BB;**>

FA	Set Data Format port A (TTL). Set serial port format using an 8-bit hexadecimal data mask. Select one of the values from the below Data Format table and pass the value to the lens in the payload of this command (without the 0x prefix)	<FAA6;**> - Set the TTL data format to 7 data bits, Odd parity, 2 stop bits.	?FA;**>
FB	Set Data Format port A (RS422/RS485). Set serial port format using an 8-bit hexadecimal data mask. Select one of the values from the below Data Format table and pass the value to the lens in the payload of this command (without the 0x prefix)	<FB07;**> - Set the TTL data format to 8 data bits, No parity, 1 stop bit.	?FB;**>
WI	Configure the lens firmware to drive the RS422/RS485 bus in 2-wire or 4-wire mode. When set to 4-wire, the transmitter is always enabled. When set to 2-wire, the transmitter is only enabled when the UART is actively outputting a character. If the RS485 bus is correctly biased, it may be acceptable to leave the lens firmware in 2-wire mode irrespective of the bus topology.	<WI2;**> - Set the RS485 bus transceiver to 2-wire mode; the transmitter is only enabled when transmitting. Valid values are WI2 and WI4. Any other value will be ignored.	?WI;**>
PS	Save parameters to Flash. This command must be issued after changing any of the above settings so that they persist after the lens power has been cycled.	<PS;**>	N/A

Data Format:

Data Bits	Stop Bits	Parity	Value
7	1	None	0x06
		Odd	0x26
		Even	0x66
	2	None	0x86
		Odd	0xA6
		Even	0xE6
8	1	None	0x07
		Odd	0x27
		Even	0x67
	2	None	0x87
		Odd	0xA7
		Even	0xE7

IMPORTANT NOTE: In order to avoid immediately losing communications to the device the values of BA, BB, FA, FB and WI do not take effect until after the device has been rebooted. Save the parameters to flash after configuring the interfaces as desired, then power cycle the lens to start using the new configuration.

It is up to the user to ensure the values stored in the lens correctly match the expected use case. For this reason, we recommend that the interface used to send the commands is kept unchanged until the interface being updated has been tested and verified for operation. Should both interfaces become mis-configured and unresponsive, the only option to recover the lens will be a factory reset where the lens may have to be returned to BOS for re-programming.

3.1.4.5 Pelco-D Support

In addition to the standard ASCII based protocol defined by BOS, the lens also supports a subset of the industry standard Pelco-D command set. The interface to be used by the Pelco-D controller must be configured to 8 data bits.

Nothing is required to be set or configured to switch between the BOS lens protocol and the Pelco-D protocol, the lens firmware simply recognises the first character in the message packet and switches protocol accordingly.

3.1.4.6 Startup

In normal use, the lens powers up with the motors disabled and unlinked. A BOS control message is sent to enable the motors and link the zoom groups before controlling the lens. Pelco-D does not have a command to do this, so the lens firmware automatically enabled the motors and links the zoom groups on receiving the first Pelco-D message (of any kind).

3.1.4.7 Pelco-D Address

The lens responds to Pelco-D commands sent to station address 1. This cannot be changed, so multiple lenses on one bus are not currently supported.

3.1.4.8 Standard Motion Command support

The lens supports the following standard commands:

CMND1	CMND2	Function
0x04	0x00	Iris Close (if Iris fitted)
0x02	0x00	Iris Open (if Iris fitted)
0x01	0x00	Focus Near
0x00	0x80	Focus Far
0x00	0x40	Zoom Wide
0x00	0x20	Zoom Telephoto
0x00	0x00	STOP

For example the byte string,

FF 01 00 40 00 00 41

(Sync Addr Cmnd1 Cmnd2 Data1 Data2 Cksum) results in the

lens zooming to wide FoV.

3.1.4.9 Extended Command support

The lens also supports the following Extended Pelco-D commands:

CMND1	CMND2	DATA1	DATA2	Function
0x00	0x25	0x00	0 - 3	Set zoom speed (0 = 25%; 1 = 50%; 2 = 75%; 3 = 100%)
0x00	0x27	0x00	0 - 3	Set focus speed (0 = 25%; 1 = 50%; 2 = 75%; 3 = 100%)
0x00	0x4F	ZOOM MSB	ZOOM LSB	Set zoom position.
0x00	0x5F	FOCUS MSB	FOCUS LSB	Set focus position.
0x00	0x55			Query zoom position. Returns the current zoom position in a 0x5D extended response.
0x00	0x73			Send FW Major/Minor Version number. Returns a 0x0173 extended response.
0x02	0x73			Send FW Build Version number. Returns a 0x0373 extended response.

3.1.4.10 Ancillaries (Heater / Thermocouple)

The lens electronics has the facility to connect a heating element and a feedback temperature probe (RTD/thermocouple) to maintain a consistent internal ambient temperature.

The heater and temperature connections are passed through to the system connector CN1 for connection to an external heater control loop. The trace connections between CN1 and the internal heater connection header can support up to 2A continuous current.

3.1.4.11 Connector Breakout PCB

For rapid evaluation of the BOS SWIR Zoom Lens, a connector breakout PCB can be provided which splits out all of the connections of the single system cable into convenient function specific terminals and connectors.

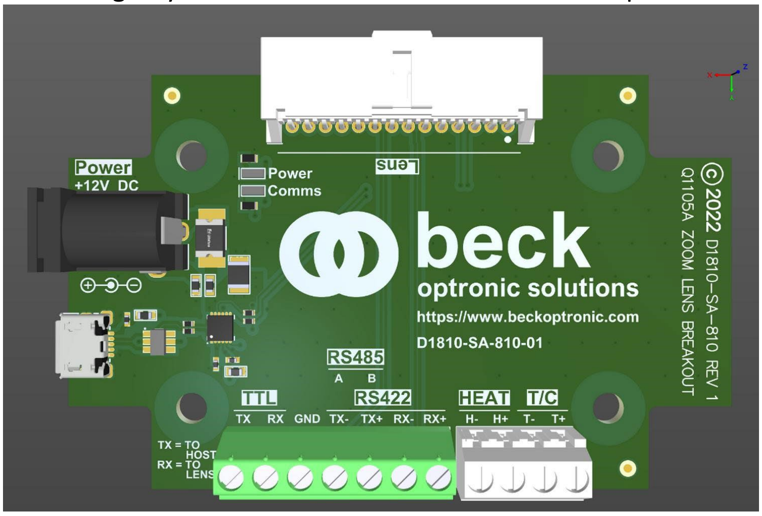


Figure 9: 3D render of Connector Breakout PCB

The lens is connected via a cable loom to the matching 14-way Micro-clasp connector.

Power for the lens can be supplied through the standard 2.1mm DC barrel jack (part number CUI PJ-102AH). This is configured centre positive and can be used with a good quality, 1A or greater, 12V AC/DC Adapter. There is a self-resettable fuse and the lens itself is protected against reverse polarity connection. The fuse will sustain up to 1.1A and has a trip threshold of 1.95A.

The TTL port A interface is passed through to the green screw terminal, and also to an on-board FTDI USB-UART for convenient connection to a laptop/PC. Most modern computers come with the drivers pre-installed. Windows 7 or older might require drivers which can be downloaded from http://ftdichip.com. The FTDI USB port will appear as a serial "COM" port and it must be set to the same baud rate as the lens in order for it to communicate. The BOS lens control panel uses 38400*bps* baud and the lens must be configured to match. RS422/RS485 port B interface is passed through to the green screw terminal. If using 2-wire, only use the terminals marked A and B. "Tx" and "Rx" is oriented from the perspective of the lens, i.e. Tx = lens transmitting to host. Heater and temperature c ontrol panel uses 38400*bps* baud and the lens must be configured to match. RS422/RS485 port B interface is passed through to the green screw terminal. If using 2-wire, only use the terminals marked A and B. "Tx" and "Rx" is oriented from the perspective of the lens, i.e. Tx = lens transmitting to host. Heater and temperature connection points are broken out to the separate 4-way screw terminal. A green LED is illuminated whenever there is power to the lens. A yellow LED flashes whenever there is activity on the USB-UART (either to the lens or from the lens), irrespective of lens power.

4 Manual Commands

The zoom lens supports multiple interfaces i.e. UART TTL, RS422 or RS485. Irrespective of which interface is chosen, the protocol for communicating with the Smart Control Card remains the same; a simple command/response always initiated by the host. Every complete command generates a single response and if the Smart Control Card fails to parse a command (e.g. due to incorrect formatting or data corruption), it will return an error response.

The protocol allows customers to easily develop software for the host system that can control lens functions and read lens status (such as Position and Travel Limits).

4.1 General Format of Commands

All commands sent to the interface follow the same general format:

<AAnnnn;CC> for instruction ?AAnnnn;CC> for queries

where:

‘<’ or ‘?’ is the literal opening character,
‘AA’ is a two letter command from the command set (uppercase only),
‘nnnn’ is an optional integer parameter,
‘;’ is a literal character separating the message from the checksum, ‘CC’ is a two character hexadecimal checksum, or the non-checksum key ‘**’, and ‘>’ is the literal message terminating character

The checksum is calculated via sum of ASCII values of all characters from the opening delimiter ‘<’ to the checksum separator ‘;’ inclusive, modulo 256 i.e. <ZS0;54> or <ZS0;**>.

The query character will only work with a subset of the commands from the list below.

The integer parameter is a decimal value, ranging from 0 to 4095 for positioning commands, and 0 to 255 for rate commands. If a value of 256 or larger is given for a rate command, the command is ignored and an error is returned.

The rate values will stop the motor when a midrange value is used (127), move forwards for values above 127, and move backwards for values below 127. (There is a deadband of about +/-10 around the 127 value)

If the parameter is not required it can be omitted. (It will be assumed to be zero if not sent)
When a query is sent, the parameter is generally omitted. A valid query (i.e. one attached to a command that allows queries) will not cause the command action to occur. If the query is not valid, the command will occur instead.

The terminating character will cause the command to be actioned when detected by the device. To cancel a malformed or unintentional command, append the terminator to what has been sent. An error message will likely be returned.

4.2 Command Set

Refer to the command list in the following table:

Command Code	Parameter	Function	Can be sent as a query?

ZS	0-255	Set main zoom axis movement rate without activating motor. Will stop motor if already moving. Mainly used as a single axis stop command with optional parameter.	No
ZP	0-4095	Move main zoom axis to specified position.	Yes
ZR	0-255	Set main zoom axis rate to the value specified and start motor.	No
YS	0-255	Set slave zoom axis movement rate without activating motor. This does not have an immediate effect if the lens is operating in the normal mode (with slave axis linked to main zoom axis). It is mainly used to stop the motor when not linked or to ensure the motor will be stopped when the link is turned off.	No
YP	0-4095	Move slave zoom axis to position. Does not operate when the slave axis is controlled by the main zoom axis. However, if the link is turned off after this command, the slave axis will then move to the commanded position.	Yes
YR	0-255	Set slave zoom axis rate and start motor. Does not affect the motor when in normal mode, as it is controlled by the main zoom axis.	No
FS	0-255	Set focus motor movement rate without activating motor. Will stop motor if already moving. Mainly used as a single axis stop command with optional parameter.	No
FP	0-4095	Move focus axis to specified position.	Yes
FR	0-255	Set focus axis rate to the value specified and start motor.	No
IS	0-255	Set iris motor movement rate without activating motor.Will stop motor if already moving. Mainly used as a single axis stop command with optional parameter.	No
IP	0-4095	Move iris axis to specified position.	Yes
IR	0-255	Set iris axis rate to the value specified and start motor.	No
XT	0-255	Set extender motor movement rate. This motor has no position feedback, except the stop/limit switches. It can be set to run forwards or backwards at any specified rate, or stopped by setting the parameter to 127. The hardware will switch off the motor when it reaches the final limit switch.	Yes (returns limit switch states)
SP	0-7	Stops or enables all motors by putting the parameter into control register CA bits 0-2 (see definition of CA register section 5.3).	No
KD	0-255	Set derivative parameter for PID loop.	No
KP	0-255	Set proportional gain parameter for PID loop.	No
KI	0-255	Set Integral gain parameter for PID loop.	No

UP	0-2047	Start profile upload to host. The number of profile values to send is (parameter + 1). The starting address is as set by the previous DA command. Note: DA + Param must not exceed 2047. Also, the DA register is self incrementing and does not retain its value, so must be reloaded each time.	No
DN	0-4095	Download one profile value from host. The value is placed at address (DA) which auto-increments. See instructions for proper use of the profile downloading mechanism.	No
DP	none	Copy the stored profile from the EEPROM to the hardware. This happens automatically at power on. If a new profile is downloaded, this command must be sent afterwards to activate it, or alternatively, power can be cycled.	No
DA	0-2047	Set profile pointer prior to UP or DN commands.	No
EP	none	Disconnect zoom and enable motors.	No
CA	0-255	Set or query control register A.	Yes
CB	0-255	Set or query control register B.	Yes
CC	0-255	Set or query control register C.	Yes
SA	none	Query status register A.	N/A
SB	none	Query status register B.	N/A
DS	none	Save current state of control registers (CB,CC, P, I and D) in EEPROM (permanent).	No

4.3 Control Registers

These registers, accessed through commands CA, CB and CC store the following settings:

Control A

Note that the PID mechanism is not critical to lens operation, and is recommended to leave this disabled. If turned on (using bits 3-5) the parameters should also be adjusted using the KD, KP and KI commands to achieve stable operation.

B0: Zoom Enable

This bit must be set in normal use. It connects the zoom slave axis to the master axis through the currently defined profile to keep the two in the correct relative position. If the slave axis is to be moved independently (using YP,YS,YR commands) this bit must be cleared, but the image will go severely out of focus.

B1: Motors Enable (All motors). If not set, motors are braked.

This bit must be set to allow any motor movement in any axis including the extender.

B2: MotorOn (Enables outputs. If not set, shafts are free)

This bit must be set to allow any motor driving in any axis including the extender.

B3: Integrate enable

Enables the integrator function in the PID control algorithm.

B4: Integrate Reset
Set this bit to hold the integrator at zero.

B5: Differentiate Enable
Enables the differentiator function in the PID control algorithm.

B6, B7 : unused

Control B
All of the bits in this register define the sense of rotation of individual motors. The standard value of this register is zero. It must not be changed or positional movements will go out of control.

B0: Z1 Motor Rotation Direction

B1: Z2 Motor Rotation Direction

B2: F Motor Rotation Direction

B3: I Motor Rotation Direction

B4: RE Motor Rotation Direction

B5: Spare Motor Rotation Direction

B6, B7 : unused

Control C
This register reverses the rotation direction that is braked by the switches. The standard value of this register is zero. It must not be changed or the corresponding motors will fail to stop when the limit switch is reached, and reversing the motor away from the switch will be impossible.

B0: Z1 Limit Switches Sense

B1: Z2 Limit Switches Sense

B2: F Limit Switches Sense

B3: I Limit Switches Sense

B4: RE Limit Switches Sense

B5: SP Limit Switches Sense

B6, B7 : unused

4.4 Status Registers

There are two status registers which provide the current positions of the limit switches. Any switch that is operated sets the corresponding bit in the status register to ‘1’.

Status register A

B0 : Iris_CW

B1 : Iris_CCW

B2 : Focus_CW

B3 : Focus_CCW

B4 : Zoom2_CW

B5 : Zoom2_CCW

B6 : Zoom1_CW

B7: Zoom1_CCW

Status Register B

B0: Crash

B1: RE_Stop_CW

B2: RE_Stop_CCW

B3: RE_Lim_CW

B4: RE_Lim_CCW

B5: 0 (unused)

B6: 0 (unused)

B7: 0 (unused)

4.5 Responses

The following response messages will be returned to the host in the event of a query being received. The device does not send unsolicited response messages.

Initiating Command	Response Format
Zoom Master position query.	!ZPnnnn;cc>
Zoom Slave position query.	!YPnnnn;cc>
Focus position query.	!FPnnnn;cc>
Iris position query.	!IPnnnn;cc>
Extender position query.	!EPn;cc>
Control Register A query.	!CAxx;cc>
Control Register B query.	!CBxx;cc>
Control Register C query.	!CCxx;cc>
Status register A query.	!SAxx;cc>
Status register B query.	!SBxx;cc>
Upload command.	!PFaaa:xxxx;cc> **
Download command.	!DNnn;cc>

where:

‘nnnn’ is a decimal value in the range 0 – 4095,
‘cc’ is either a checksum in hex, or characters **,
‘n’ is a single digit 0-3,
‘xx’ is a 2-digit hexadecimal,
‘aaa’ is a 3 digit hexadecimal address,
‘xxxx’ is a 4 digit hexadecimal data value,

'nn' is an index number between 0 and 31.

** A series of these upload messages is transferred until the count is exhausted.

4.6 Error List

If an error occurs, the device can send an error message to the host. On occasion, a single command can generate 2 or more errors. The format for an error message is as follows:

!?n;cc>

Which follows the normal convention for replies from the device, but with "?n" as the message type where n is taken from the following list:

Value of n	Error Type
0	No error (this should never be returned).
1	No Data. Expecting a message but nothing was found. This may happen occasionally if the device processes a message from it's input buffer before the message ready flag is generated.
2	Busy Hardware error. Trying to send or receive when RS422 or RS485 is already running.
3	Full. Software serial input or output buffer overflow.
4	Error. General error (unknown type).
5	Unknown Command.
6	Parameter too big. Trying to fit bigger than 255 into a rate register.
7	Invalid Profile. Trying to initialise hardware without a valid profile in memory.
8	Checksum error.
9	Parity error.

4.7 Power Saving

This design provides the ability to turn off the motors without having to power down the device. There is a global motor disable in the control register CA, which can be used either to turn off all the H Bridge devices (motors freewheel), or set them to short the motors to ground (Motor braking option)

The motors can also be individually turned off by transmitting a rate setting command to the appropriate axis.

With the motors off, audible and electromagnetic noise is eliminated, and the PCB power consumption is minimised. This is preferred to turning off the hardware altogether, unless for a very long period.

4.8 Creating and Using Profiles

The device stores the zoom profile in EEPROM memory, and automatically loads this into the hardware when power is turned on. There is no need to do anything with this in normal use.

It is possible to carry out the following operations using the interface protocol:

- Create a new profile by moving the master and slave zoom axes into focus independently and saving the resulting data in a disk file. Generally, a number of points (around 10 to 40) would be set up, and curve fitting used to generate the remainder
- Download a profile from disk file to device EEPROM
- Upload a profile from EEPROM for verification, or to save it on a disk
- Edit an existing profile to improve it.

NB: altering the settings of any of the potentiometers on the PCB will have a considerable effect on the current profile, which will no longer be useful.

When working with profiles, note that there are 2048 values stored in EEPROM, corresponding to every alternate code from the 12 bit ADCs. These are stretched by linear interpolation to the full 4096 values when copied from EEPROM into the active hardware. The upload and download commands operate only on the 2048 values. When calculating profiles, remember that there is a factor of 2 between the reported master zoom ADC position, and the corresponding entry in the EEPROM file. Thus EEPROM entry 1000 saves the master/slave profile point for when the master zoom ADC is at 2000. There is no similar scaling for the slave zoom values.

The microcontroller erases EEPROM in blocks of 32 words (not bytes). Therefore, profiles must be downloaded in blocks of this size or multiples of it. The erasure is automatic and need not be considered. However, the data must be downloaded to EEPROM words 0-31, or 32-63 etc, with each block loaded in self consistent order. From block to block, random access is possible by writing a different DA address – e.g. write 0-31, followed by 512-543. However within a block all 32 words must be written in order.

For example:

> Send a DA command with parameter 128.
> (EEPROM address 128 is the start of address block 5 based on 32 word blocks) Send 32 data values to store from address 128 to 159 in ascending order.
> (As each is sent, an acknowledgement reply is returned: “DN0” to “DN31”) When DN31 is received, the device will erase the EEPROM block, and store all the data in it.

Now another DA should be sent, to write a different block e.g. “DA160” (The device will treat consecutive ascending blocks correctly, even if the successive DA commands are omitted).

NB: The acknowledgement messages only have parameters 0-31, which tell you how many entries have been downloaded in the current block. When 31 is acknowledged, the device automatically starts the EEPROM erase/write cycle. This takes several milliseconds to finish, and a pause should be allowed before sending more characters to the interface.

About Beck Optronic Solutions

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