

Polarizer Rotator

User Manual



Altechna

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Polarizer Rotator

February 2015

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1. Introduction

This user manual is designed to help to assemble, install and configure Polarizer Rotator. Before installing and operating Polarizer Rotator please read this manual carefully. Safety instructions must be read carefully as well. If there are any questions about contents of this manual please contact info@altechna.com. *Altechna* reserves the right to update contents of this manual without any notification.

1.1. Polarizer Rotator short description

Motorized Polarizer Rotator is a set of computer controlled rotation stage and its controller, that communicated with external computer via USB interface. It also has “STEP/DIR INTERFACE” connector for controlling via other devices. The product is intended for advanced, users who wish to control the polarizer rotation via their own software or via terminal commands thus controller’s command library is provided in this manual.

Note:

Altechna provides software developed for $\lambda/2$ waveplate operation in the rotator along with static polarizer. This setup is well known as polarization manipulation based laser attenuator. The software for this configuration is named “Watt Pilot” and is available for download at www.altechna.com.

1.2. General safety requirements

Motorized Polarizer Rotator is designed to operate in conjunction with laser system. All applicable rules and regulations for safe operation of lasers must be known and applied while installing and operating Polarizer Rotator. The customer is solely responsible for laser safety while using Polarizer Rotator as standalone

device or integrated into system. The customer must consider protective measures.

While assembling or operating Polarizer Rotator, do not stare at the direct or scattered laser light even with safety goggles. All parts of the body must be kept away from the laser radiation. While adjusting laser beam through Polarizer Rotator, laser power must be kept as low as possible. Hazardous laser radiation can increase while optical components or instruments are used in combination with Polarizer Rotator. Appropriate eye protection must be worn at all times. Electrical safety requirements must be complied while assembling and operating Polarizer Rotator.

1.3. Symbols

Warning!

Sections marked with this symbol explain dangerous situations that can result as personal injury or death. Always read the associated information carefully, before performing indicated procedure.

Attention!

Paragraphs preceded by this symbol explain hazards that could damage the instrument and connected equipment or may cause loss of data.

Note:

This manual also contains “NOTES” and “HINTS” written in this form.

1.4. Regulation

Attention!

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the accompanying documentation.

These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can create radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference with radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment causes harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Altechna is not responsible for any radio or television interference caused by modifications of this equipment or the substitution or attachment of connecting cables and equipment other than those specified by *Altechna*. The correction of interference caused by unauthorized modification, substitution or attachment will be treated as responsibility of the user.

Attention!

Cellular phones or other radio transmitters are not recommended to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to IEC 61326-1.

1.5. Operating and storage conditions

For proper Polarizer Rotator functioning please use assigned controller (found in the same package). Using unassigned controller might be harmful to the device.

Environmental conditions that must be hold while storing, servicing and operating are:

- Storage temperature should be between -25 °C and +60 °C.
- Operating temperature is 25 °C ± 10 °C.
- Polarizer Rotator must be protected from humidity, dust and corrosive vapors to avoid damaging optical components and electronics.
- Avoid strong static electricity and electromagnetic fields.

2. Package contents

2.1. Polarization rotator components

- Motorized polarizer rotator:
- Controller
- USB cable (2m length recommended but no longer than 3m)
- 12V power supply
- Software, installation instructions in USB flash
- Two waveplate retaining rings and tightening wrench

2.2. Optics assembling

Note

Powder free gloves must be worn while mounting optical components. Avoid touching or scratching optical surfaces.

Polarizer rotator assembling steps:

- **Step 1.** Put the optics (e.g. wave plate) into the rotator between two mounting rings as shown. Be sure the optics is immobilized tightly.
- **Step 2.** Connect Polarizer totator to the controller box via RS232 plug from the micro step motor.
- **Step 3.** Connect controller box to PC via USB cable.
- **Step 4.** Connect control unit power supply.

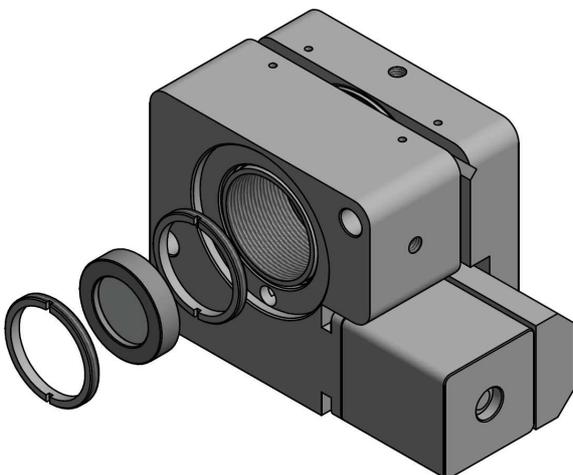


Figure 1. Assembling waveplate into the Polarizer holder.

3. Polarizer Rotator Controller Hardware

3.1. Controller specifications

Polarizer Rotator controller is bipolar stepper motor driver with

specifications listed in Table 1 below.

Table 1. Controller specifications

Characteristic	Rating
Max output voltage	+12 V
Max output current	2 A
Current regulation type	Pulse Width Modulation
Microstepping capability	Full, Half, Quarter, Eight, Sixteen steps
Step frequency	Up to 4 kHz
Position feedback	Open loop operation (no external position feedback encoder)
Controller protection	Driver have overheating and over current (2A) protection
Device can be operated by	<ul style="list-style-type: none">• Step Dir pulses• Computer software via USB port• Microcontroller via UART connection
Limit switch	One limit switch can be connected

Advanced feature is “STEP/DIR INTERFACE” connector, which enable controller to be used with custom electronics, not only computer based applications.

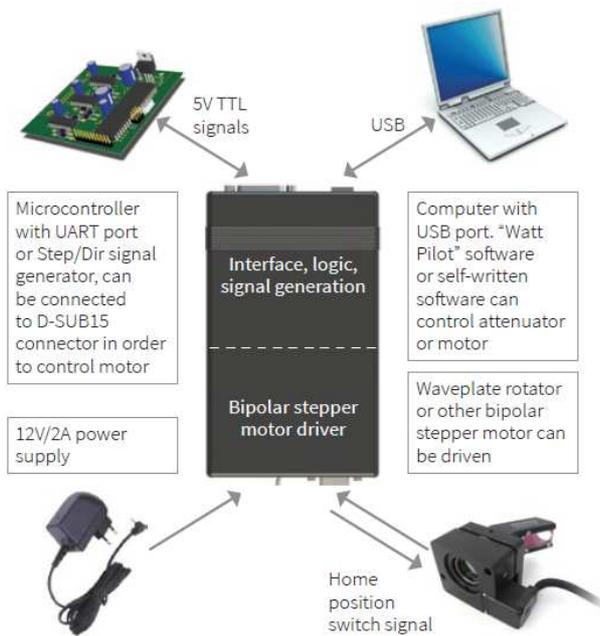


Figure 2. Illustration of Polarizer Rotator controller advanced features.

3.2. Controller connections

Polarizer Rotator front and rear connectors are shown in the pictures below.



Figure 3. Controller front view.

- **USB connector** is used to control Polarizer Rotator with computer.
- **Firmware upgrade button** is hidden under small hole, highlighted by arrow. Used to recover if firmware upgrade process crashed. See “TROUBLESHOOTING” on page 38 if necessary.
- **“STEP/DIR INTERFACE” connector** can be used to control Polarizer Rotator with microcontroller via

UART or “Sep-Dir” pulses. See section Operation modes: “Step-Dir” mode on page 20.



Figure 4. Controller rear view.

- **Controller power supply socket.** Plug dimensions: outer diameter - 5.5 mm (GND), central pin diameter - 2.1 mm (+12 V). Polarizer Rotator requires +12 VDC/2 A power supply.
- **“ON/OFF” switch.** Green led indicates that controller is ON.
- **“MOTOR” connector,** 9 pin D-SUB female. Connect it to Polarizer Rotator attenuator. See ““MOTOR” connector pin out” on page 24 for more information.

Note:

Controller can be used to drive various bipolar stepper motors, not only Polarizer Rotator attenuator. Stepper motor, for example, is also widely used to control linear, so this controller can be used to control them. See “Supported Stepper Motors” on page 25 about such capability.

3.3. Controller internal block diagram

Polarizer Rotator controller consists of three blocks. Each is shown in Figure 5.

- **Motor driver.** This block drives motor by controlling currents in motor windings, according to Step/Dir/ Enable and motor power signals.
- **Command parser.** This block parses commands, acquired from USB or UART, depending on switch A state (SWA). The state of switch A can be changed by logic level on input “UartOn” in “STEP/DIR

INTERFACE” connector. Also this block can select which Enable and Dir signals to use in “Step-Dir” mode: internally generated or picked up from “STEP/ DIR INTERFACE” connector pins. Switch E and F are used for this purpose.

- **Internal Step/Dir signal generator.** This block generates acceleration, continuous speed and deceleration step pulses. Also DIR and enable signals when controller is working in “Command” mode.

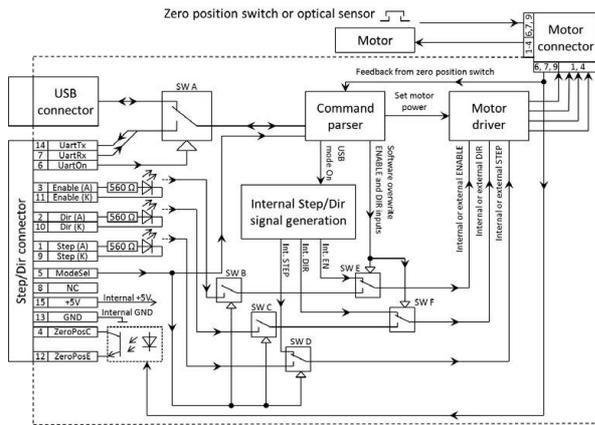


Figure 5 Block diagram of Polarizer Rotator controller.

3.4. Operation modes: “Command” mode

This is the first of two possible controller operation modes. “Command” mode is selected if pin5 (ModeSel) is left unconnected in front “STEP/DIR INTERFACE” connector.

Motor position is set by sending ASCII commands to controller. Controller has USB and UART interfaces for communication. “STEP”, “DIR”, “ENABLE” inputs are disconnected in this mode. Polarizer Rotator appears as “virtual serial port” in computer device list when connected. “Polarizer Rotator” software uses this port to change attenuation. It is easy to write own program to integrate with controller. Device can be accessed by any serial port program. USB drivers are available for Windows, Windows CE, Mac or Linux (see “List of supported operating systems for USB drivers” on page 26). Serial commands are listed in “Serial commands and protocol” on page 27.

Apart from USB, UART connection is available in “STEP/DIR INTERFACE” connector. It can be used to communicate with

microcontroller or prolong cable length with RS232 level shifter. See ““STEP/DIR INTERFACE” connector pin out and specifications” on page 21.

Attention!

“Polarizer Rotator” software only supports “Command” mode and only via USB connection. It will not work if RS232 level shifter is used.

Attention!

UART pins are connected directly to controller’s microprocessor, which is 5 V device. RS232 to 5 V UART converter must be used to connect device to PC, for example, MAX232 chip can be used for this.

3.5. Operation modes: “Step-Dir” mode

This is the second of two possible controllers’ operation modes. “Step-Dir” mode is selected by connecting pin5 (ModeSel) to pins13 (GND) in “STEP/DIR INTERFACE” connector.

USB connection and computer are not necessary in this mode. Motor rotates according to electric signals applied to “STEP/DIR INTERFACE” connector. These signals are called “STEP” (pins 1, 9), “DIR” (pins 2, 10), and “ENABLE” (pins 3, 11). “DIR” signal sets rotation direction of the motor (0V – motor rotates counterclockwise, +5V – motor turns clockwise). Voltage transitions from 0 V to +5 V on “STEP” input advances motor per one step. +5 V on “ENABLE” pin will reduce motor current to “Standby current” value set in settings and “STEP” signal is ignored. Otherwise, “Motion current” flows to motor and “STEP” pulses rotate the motor. Use “ENABLE” input to reduce motor heating. More details can be found in ““STEP/DIR INTERFACE” connector pin out and specifications” on page 21.

Attention!

Motor current is set by “ENABLE” signal, so leaving it high can overheat the motor, so proper “ENABLE” handling must be implemented (by wiring or by using commands).

Attention!

STEP/DIR current” setting value is used to control old controllers (with “4ATT” serial number) and newer controllers with “5ATT” serial number, but with outdated firmware. If “ENABLE” pin is high, motor is completely disconnected. This causes lack of holding torque on idle state and step position could be lost. This was fixed for “5ATT” controllers in firmware version v8 released on August 22, 2012 and newer controllers. “STEP/DIR current” setting is abandoned in latest controllers.

3.6. “STEP/DIR INTERFACE” connector pin out and specifications

“STEP/DIR INTERFACE” connector is used to operate controller in “Step-Dir” mode or use UART interface instead USB. The type of connector is 15 pin D-SUB female.

Table 2. “STEP/DIR INTERFACE” connector pin out.

Pin No.	Name	Type
1	Step (A)	In (Optocoupler anode)
2	Dir (A)	In (Optocoupler anode)
3	Enable (A)	In (Optocoupler anode)
4	ZeroPosC	Open Collector
5	ModeSel	In (Pulled up to +5 V)
6	UartOn	In (Pulled up to +5 V)
7	UartRx	In
8	Not Connected	
9	Step (K)	In (Optocoupler cathode)
10	Dir (K)	In (Optocoupler cathode)
11	Enable (K)	In (Optocoupler cathode)
12	ZeroPosE	Open Emitter
13	GND	Controller ground
14	UartTx	Out
15	+5 V	Power output

Table 3. “STEP/DIR INTERFACE” connector electrical specifications

Input pins	Description
UartRx	UART baud rate 38 400, 8 data bits, 1
UartTx	stop bit, no parity. RXD and TXD pins are +5 V compatible with reference to GND pin. Maximum input voltage is +5.5 V
Step/Dir/En	These pins are optically isolated, 3.3 V – 5 V compatible. Input current requirement per pin: 4.6 mA @ +2.8 V 5.2 mA @ +3.3 V 6.8 mA @ +5 V
ModeSel	These logic pins are 5V compatible with reference to GND pin. Maximum input voltage is +5.5 V
UartOn	reference to GND pin. Maximum input voltage is +5.5 V

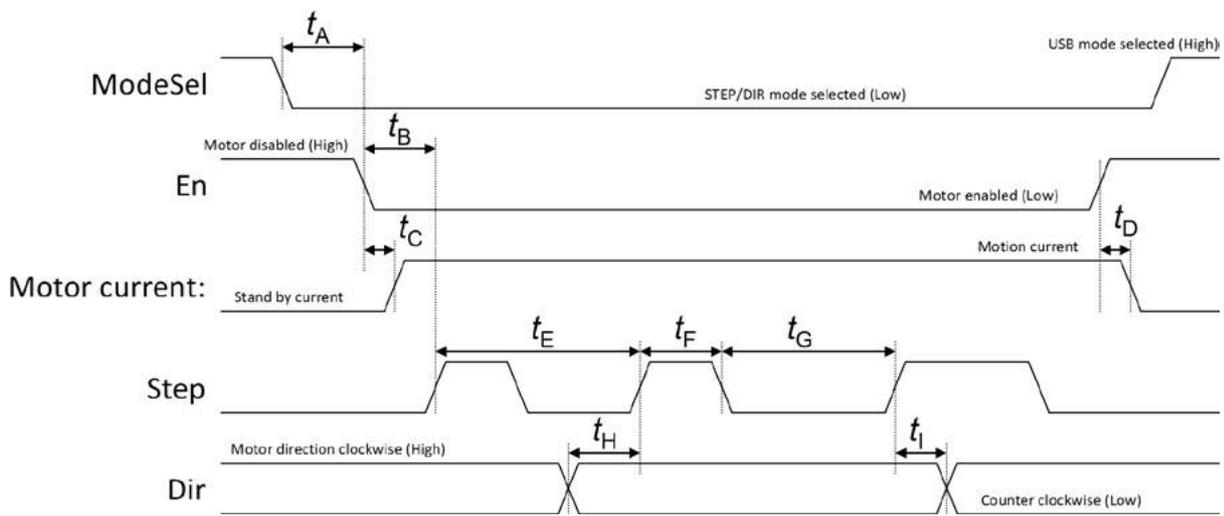
Below is the description of “STEP/DIR INTERFACE” pins.

- Step (A), Step (K). +3.3 V - 5 V compatible input to optocouplers anode Step (A) and cathode Step (K). Rising edge on Step (A) pin with reference to Step (K) advances motor by 1 step in “Step-Dir” mode. Motion direction depends on Dir signal level.

All stepper motors suffer from resonance. Polarizer Rotator rotator tends to resonate at frequencies from 100 to 300 Hz, so such low “STEP” frequencies should be avoided in “Step-Dir” mode. Vibration can be eliminated by setting higher micro stepping in settings.

It is necessary to mention that motor shaft is inert. Frequency of STEP signal should be controlled linearly, especially at high motor speeds. Motor should accelerate and decelerate smoothly. For instance, control logic must sweep down STEP frequency before changing DIR level. Similarly, frequency must be swept up then reaching high motor speed.

“Step-Dir” mode signal timing requirements are shown in Figure 6.



Symbol	Description	Min.	Typ.	Max.	Unit
t_A	ModeSel wait time. Controller switches to "Step-Dir" mode after ModeSel pin goes low	1			s
t_B	Wait time for first valid STEP pulse after "En" pin goes low	20			ms
t_C	Time constant then motor current reaches motion current value after "En" pin goes low	15	18	20	ms
t_D	Time constant then motor current reaches stand by current value after "En" pin goes high	15	18	20	ms
t_E	STEP pulse period	35			μ s
t_F	STEP high-level time	5			μ s
t_G	STEP low-level time	10			μ s
t_H	DIR setup time	5			μ s
t_I	DIR hold time	7			μ s

Figure 6. "Step-Dir" mode input signal timing requirements.

- Dir (A), Dir (K). 3.3 V - 5 V compatible input to optocoupler anode Dir (A) and cathode Dir (K). This input controls motor direction in “Step-Dir” mode. +5 V on Dir (A) pin with reference to Dir (K) sets motor direction clockwise. This input can be overridden by command parser – see “Serial commands and protocol” on page 27 and Figure 5 (SW F) on page 19 for details.
- Enable (A), Enable (K). 3.3 V - 5 V compatible input to optocoupler anode Enable (A) and cathode Enable (K). This input reduces motor current in in “Step-Dir” mode. +5 V on Enable (A) pin with reference to Enable (K) reduce motor current to “Standby current” value set in controller settings. Otherwise, “Motion current” flows to motor and “STEP” pulses rotate the motor. This input can be overridden by command parser – see “Serial commands and protocol” on page 27 and Figure 5 (SW F) on page 19 for details.

- ZeroPosC, ZeroPosE. These pins are used to sense zero position switch state. Phototransistor is open (low resistance state) if pin 7 in “MOTOR” connector is 0 V. and closed (high resistance) if pin 7 is +5V – logic high. “6ATT” controllers come with attenuator, which optical sensor output is normally high, and 0 V if rotator is in zero position. Pin 7 is CMOS input with absolute maximum voltage rating +5.5 V.

Attention!

Motor current is set by “ENABLE” signal, so leaving it high can overheat the motor, so proper “ENABLE” handling must be implemented (by wiring or by using commands). Only mechanical limit switch can be attached to “4ATT” or “5ATT” controllers, because input circuit is different from “6ATT” controllers, it is shown in the picture below

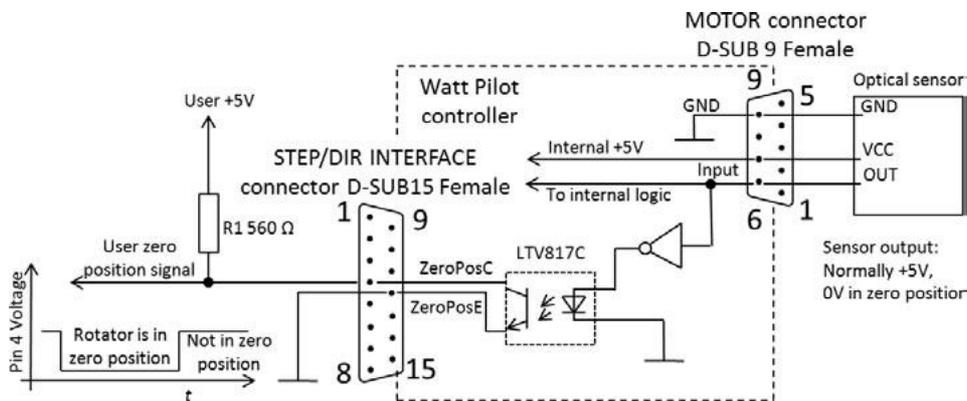


Figure 7. Zero position input circuit diagram for controllers with serial numbers starting with “6ATT”.

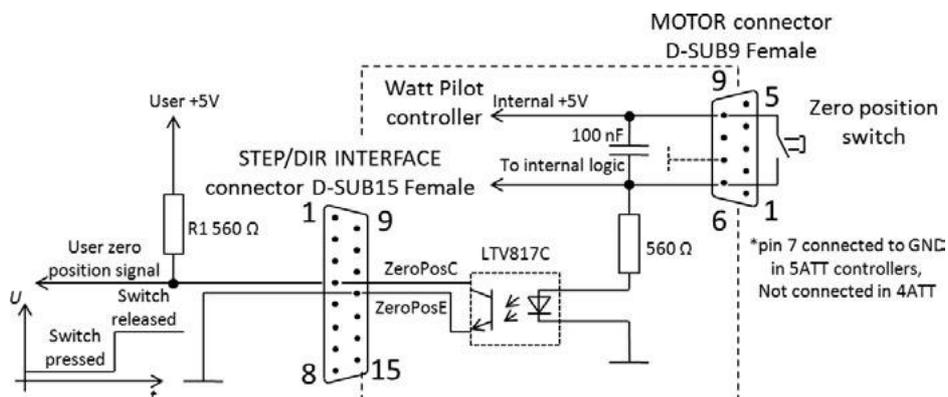


Figure 8. Zero position input circuit diagram for controllers with serial numbers starting with “4ATT” and “5ATT”.

Warning!

“6ATT” controllers support every Polarizer Rotator attenuator, but “6ATT” attenuator cannot be driven by “4ATT” or “5ATT” controller.

Note

Because of mechanical zero position switch, zero position optocoupler signal should be debounced or used only first voltage spike detected for accurate zero position detection.

- **ModeSel.** Then this pin is connected to GND pin (13), controller switches into “Step-Dir” mode. If this pin is left unconnected or applied +5 V with reference to controllers ground (pin 13), Step/Dir/Enable inputs become disconnected and controller works in “Command” mode. ModeSel pin controls internal switches SW B, SW C, SW D (“Controller internal block diagram” on page 19). ModeSel pin is not optically isolated and is pulled up to internal +5 V (See “Polarizer Rotator controller connection examples and input circuit diagram” on page 26).
- **UartOn.** This pin controls internal switch SW A, which sets command path to the command parser (“Controller internal block diagram” on page 19). Then this pin is connected to GND pin (13), controller is accessed by 5V UART interface (“UartRx” and “UartTx” pins) instead of USB port. Useful, if controller is operated by user’s microcontroller/FPGA. All “Command” mode commands are valid. If this pin is left unconnected or applied +5 V with reference to GND, command parser gets commands via USB port. UartOn pin is not optically isolated and is pulled up to internal (See “Polarizer Rotator controller connection examples and input circuit diagram” on page 26).

Attention!

“Polarizer Rotator” software only supports “Command” mode and only via USB connection. It will not work if RS232 level shifter is used

Attention!

UART pins are connected directly to controller’s microprocessor, which is 5 V device. RS232 to 5 V UART converter must be used to connect device to PC, for example, MAX232 chip can be used for this. Table 4. “MOTOR” connector pin out

- **UartRx, UartTx** - 5 V UART input and output pins, see UartOn pin description. These pins are not optically isolated. If galvanic isolation is needed, special integrated circuits can be used, for example ADUM1201.
- **GND.** Ground pin of controller internal circuit it is reference for ModeSel, UartOn, UartRx and UartTx pins.
- **+5V.** Internal controller +5 V. Can be used for external circuitry and can supply up to 25 mA of current.

3.7. “MOTOR” connector pin out

“MOTOR” connector is used to connect bipolar stepper motor and home limit switch to controller. The type of connector is 9 pin D-SUB female.

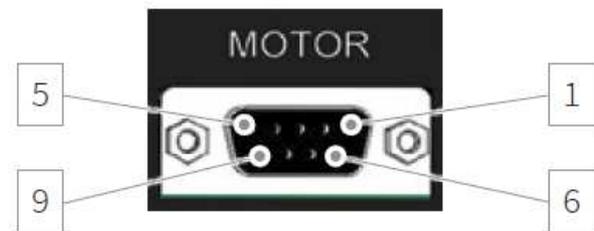


Figure 9. Controller “MOTOR” connector.

Table 4. "MOTOR" connector pin out

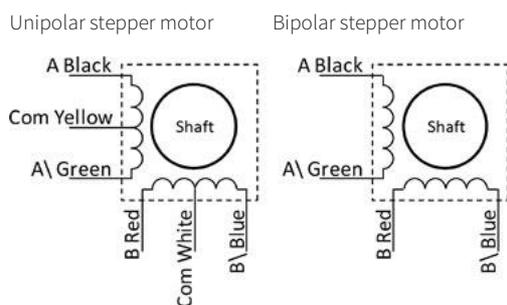
Pin No.	Controller serial number begins with:		
	"4ATT", see Figure 8 on page 23	"5ATT", see Figure 8 on page 23	"6ATT", see Figure 7 on page 23
1	Motor winding B output (usually red wire)		
2	Motor winding B\ output (usually blue wire)		
3	Motor winding A\ output (usually green wire)		
4	Motor winding A output (usually black wire)		
5	No connection	No connection	No connection
6	Zero position switch return	Zero position switch return	Zero position CMOS input with pullup to +5 V
7	No connection	GND	+5V power supply for optical sensor, up to 70 mA
8	No connection	No connection	Pull up to +5 V, not used
9	Zero position switch	Zero position switch	GND

Connector pin out changes were made in controller hardware revisions. Only mechanical limit switch can be used with controller serial numbers “4ATT” and “5ATT”, connected to pins 6 and 9. Latest Polarizer Rotators with “6ATT” serial number come with optical home position sensor on rotator, so limit switch input circuit is essentially different from previous hardware versions. See Figure 7 on page 23 and Figure 8 on page 23 for differences. “6ATT” rotators are not compatible with “4ATT” or “5ATT” versions of controllers. All versions of rotators can be used with “6ATT” controllers.

3.8. Supported Stepper Motors

There are two types of stepper motors: unipolar and bipolar. Controller supports bipolar stepper motors. In order to use unipolar motor as bipolar, center wires from both windings must be left unconnected.

Motor winding resistance multiplied by motor current must be less than 11.5 V. Controller can drive up to 2 A maximum current and 1.6 A continuous. ST2818S1006 stepper motor can be chosen as reference for motor requirements, because it is used as waveplate rotator.



Motor wire	Controller pin number
A	4
Com (Yellow)	Leave unconnected
A\	3
B	1
Com (White)	Leave unconnected
B\	2

Figure 10. Using unipolar motor as bipolar.

Table 5. Stepper motor ST2818S1006 electrical characteristics

Winding voltage	2.66 V
Winding Current	0.95 A
Winding Resistance	2.8 Ω

Resistance of motor windings usually is less than 10 Ohms, so wires to the motor, must be as short as possible and with significant wire diameter (>0.75 mm², or ≤20 AWG) to minimize wiring impact to motor noise.

3.9. Polarizer Rotator controller connection examples and input circuit diagram

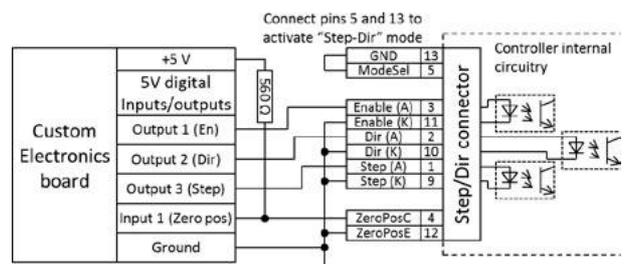


Figure 11. Connecting external equipment to use Polarizer Rotator controller in “Step-Dir” mode.

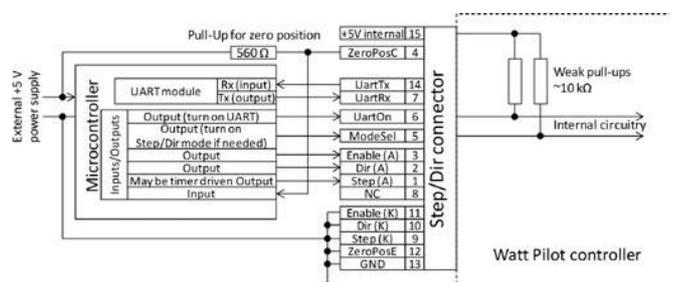


Figure 12. Connecting Polarizer Rotator controller to microcontroller employing all of Polarizer Rotator features

4. Writing Software for Polarizer Rotator

4.1. List of supported operating systems for USB drivers

In order to communicate with Polarizer Rotator, USB drivers are necessary. These are available for more operating systems than “Polarizer Rotator” software.

Virtual USB-Com port drivers can be installed on

- Windows 2000 (32-bit)
- Windows XP (32-bit)
- Windows Server 2003 (32-bit)
- Windows Vista (32/64-bit)
- Windows Server 2008 (32/64-bit)
- Windows 7 (32/64-bit)
- Windows 8 (32/64-bit).

There is no need to install any drivers on modern Unix-like (Linux, MAC) operating systems. Polarizer Rotator is automatically recognized and installed as “ttyUSB” device after connecting it to computer. You can check which serial port is assigned in your UNIX machine with command „root | dmesg | grep cp210x”.

4.2. Serial port parameters

Serial port parameters to be used are shown in a table below.

Table 6. Serial port parameters

Baud rate	38400
Parity	None
Handshaking	None
Stop bits	1

4.3. Identifying serial port name

First step to control Polarizer Rotator using serial port and commands would be to find out which serial port is assigned for device. This can be seen in Polarizer Rotator “Selector” window list – see section “Polarizer Rotator “Selector” window” on page 11.

In case only drivers were installed (no “Polarizer Rotator” software itself – see “Computer requirements” on page 8) serial port name could be checked in Windows “Computer manager”. Right click on “My Computer” (1), select “Manage” (2). “Computer manager” window will appear. Click on “Device Manager” under “Computer Management” tree (3) and look for “Ports (COM and LPT)” (4). Each connected and powered on attenuator appears as “Silicon Labs CP210x USB to UART Bridge (Serial port name)”. Serial port name is shown in parentheses, as seen in the picture below.

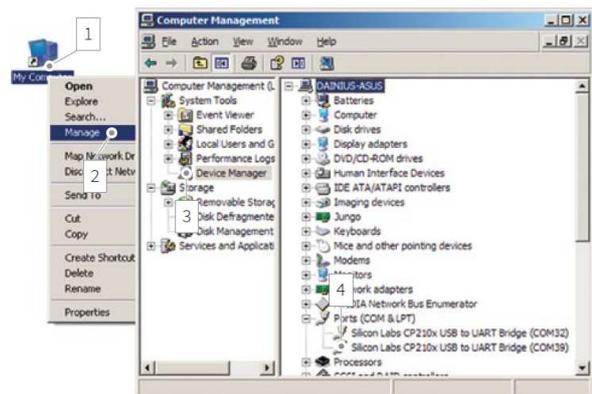


Figure 13. Finding Polarizer Rotator serial port name using Windows “Computer Manager”.

Third way to identify Polarizer Rotator is to open each serial port and send “p” command. If attenuator is present on that port, it will send back string starting with “USB”, as listed in “Serial commands and protocol” on page 27. If device is not present, no bytes will be received or received string will not begin with “USB”. Serial port read timeout can be set to 50ms to speed up scanning process. This method is universal and can be used with any operating system. Read next chapters about serial port parameters and command list.

Linux users can find Polarizer Rotator port by executing command “root | dmesg | grep cp210x”:

```

root@Aivaras:/home/Aivaras# installpkg Downloads/cutecom-0.22.0-i486-las
Verifying package cutecom-0.22.0-i486-las.txz.
Installing package cutecom-0.22.0-i486-las.txz:
PACKAGE DESCRIPTION:
# CuteCom (A graphical serial terminal, like minicom)
#
# It is aimed mainly at hardware developers or other people who need a
# terminal to talk to their devices. It is free software and distributed
# under the GNU General Public License Version 2, which can find in the
# file COPYING.
# Cutecom is heavily inspired by Bray++ for Windows
#
#
Package cutecom-0.22.0-i486-las.txz installed.

root@Aivaras:/home/Aivaras# cutecom
No protocol specified
cutecom: cannot connect to X server :0
root@Aivaras:/home/Aivaras# dmesg | grep cp210x
[ 515.118805] USB Serial support registered for cp210x
[ 515.118847] cp210x 5-1:1.0: cp210x converter detected
[ 515.355645] usb 5-1: cp210x converter now attached to ttyUSB0
[ 515.355685] usbcore: registered new interface driver cp210x
[ 515.355691] cp210x v0.09:Silicon Labs CP210x RS232 serial adaptor dr:
[ 1196.500459] cp210x ttyUSB0: cp210x converter now disconnected from tt
[ 1196.500493] cp210x 5-1:1.0: device disconnected
[ 1202.112687] cp210x 5-1:1.0: cp210x converter detected
[ 1202.340780] usb 5-1: cp210x converter now attached to ttyUSB0
root@Aivaras:/home/Aivaras#

```

Figure 14. Finding Polarizer Rotator serial port under Linux. Screenshot is taken on Slackware Linux 13.37 32 bit OS.

In the picture above we can see that one Polarizer Rotator (cp210x) device is assigned to “ttyUSB0” port. There is also shown installation command for “CuteCom” package, which is easy to use terminal application with GUI.

4.4. Serial commands and protocol

Polarizer Rotator is a slave device and computer is a master device. That means that PC sends data requests to attenuator, and attenuator must respond. Polarizer Rotator itself will never send data to computer without request, except of two cases: if “Report zero position” command “zr” setting is set; also string “USB Mode\r\n” is sent upon controller start if controller starts in “Command” mode.

Polarizer Rotator controller writes all received bytes to internal buffer. If it receives “carriage return” symbol (or ‘\r’ in C++ denotation, 13th symbol in ASCII table, or 0x0D in hex), device will try to parse received bytes as a command string and will execute it. Attenuator echoes back every byte it receives back to computer except for ‘\r’. Symbol echoing is essential for users who literally type commands in terminal window. This enables user to see what data is sent to device, because not all terminal

programs has a text field where sent symbols are shown. “\n” (0x0A) symbol is treated like all other symbols.

Polarizer Rotator will respond to byte ‘\r’ by sending additional data, if command requires it. Additional data is terminated with “\r\n” symbols. Termination symbols “\r\n” are essential for users who literally type commands in terminal window. These symbols are not visible, but they format “received data” window text so it looks organized.

From computers perspective each command is ended by byte ‘\r’. Common terminal programs usually send this symbol by pressing “Enter”. Command and command parameter is separated by space symbol (0x20). For example, typing such string “g 3000” in terminal application and pressing “Enter” will drive waveplate rotator to absolute position of 3000 steps. Here “g” (0x67) is a command, space (0x20) is a separator, and “3000” (0x33, 0x30, 0x30, 0x30) is a command parameter, which corresponds to 3000 steps. All sent bytes in hexadecimal will be (0x67, 0x20, 0x33, 0x30, 0x30, 0x30, 0x0D), including command end symbol ‘\r’, or “Enter” key press. New command can be sent after 50 ms.

There is no command acknowledge in protocol, so 50 ms delays between commands must be inserted. Otherwise command misinterpretation can occur. See table below for command list.

Table 7. Serial command list

ent x	This command is effective only in “Step-Dir” mode.
	Controls software disconnecting of “Enable” input pin (switch SW E – see Figure 5).
	Parameter x:
1	“Enable” pin is disconnected, motor is enabled.
0	“Enable” pin is disconnected, motor is disabled.

off motor power is controlled by signals on “Enable” input pin in “STEP/DIR INTERFACE” connector.

Example:

“ent off” – motor power is controlled by input pin. Now send “ss” to save this setting to controller.

dir x This command is effective only in “Step-Dir” mode.

Controls software disconnecting of “Dir” input pin (switch SW F – see Figure 5).

Parameter x:

cw “Dir” pin is disconnected, motor direction is clockwise.

ccw “Dir” pin is disconnected, motor direction is counterclockwise.

off motor direction is controlled by signals on “Dir” input pin in DB-15 connector.

Example:

“dir ccw” – set motor direction counterclockwise. Now send “ss” to save this setting to controller.

m x Move motor by x steps.

Parameter x:

Integer number. Can be positive (motor turns clockwise) and negative (motor turns counterclockwise). Place “-“ for negative notation. x can be in range of -2147483646..+2147483646.

Example:

“m 1000” to move 1000 steps clockwise and “m -1000” to move 1000 steps counterclockwise.

g x Go to absolute coordinate.

Parameter x:

Integer number. Can be positive and negative.

Place “-“ for negative notation. x can be in range of 2- 147 483 646..+2 147 483 646.

Example:

“g -400” – motor turns while internal step counter reaches 400. Then send “m 1000” to move 1000 steps clockwise. Now motor stands in 600 position.

i x Set coordinate counter to specific value.

Parameter x:

Integer number. Can be positive and negative.

Place “-“ for negative notation. x can be in range of 2- 147 483 646..+2 147 483 646.

Example:

“i 625” – set coordinate to 625. Now send “so” to save position to controller.

h Resets coordinate counter to 0.

st Stop motor smoothly if it is currently running.

This is preferred command to stop motor instead of “b”.

b Make movement immediately.

This command stops motor, but step counter accuracy can degrade using Polarizer Rotator.

zp Go to hardware zero position and reset step counter.

Use this command to return waveplate to its home position, determined by zero position switch. Then motor stops controller stores 0 in coordinate counter and saves this value.

rx Set motor micro stepping resolution.

Parameter x:

- 1 Motor is driven in full steps mode. Waveplate holder turns once in 15600 steps for standard attenuator or 36000 for big aperture.
- 2 Half step mode. Waveplate holder turns once in 31200 steps.
- 4 Quarter step mode. Waveplate holder turns once in 62400 steps.
- 8 Eight step mode. Waveplate holder turns once in 124800 steps.
- 6 Sixteen step mode. Waveplate holder turns once in 249600 steps.

Higher micro stepping levels demonstrate better position accuracy and no motor resonance. It is advisable to use half stepping operation mode.

ws x Set motor current then it is idles. This removes motor heat. Some amount of current must be left in order to keep position accuracy.

Parameter x:

Integer number in range of from 0 to 255. Motor current can be calculated using such equation: $I=0.00835x$ (A)

wm x Set motor current then it moves.

Parameter x:

Integer number in range of from 0 to 255. Motor current can be calculated using such equation: $I=0.00835x$ (A)

wt x Set motor current then controller operate in “STEP/DIR” mode. There is no automatic current control like stand by current in “USB” mode. Current can be cut only by logic high on “Enable” input. This applies only for “4ATT” or “5ATT” controllers with firmware version v7 or lower. This command is absent for “5ATT” and “6ATT” controllers with firmware v8 and higher.

Parameter x:

Integer number in range of from 0 to 255. Motor current can be calculated using such equation: $I=0.00835x$ (A)

a x

Set acceleration.

Parameter x:

Integer number in range of from 0 to 255. 1 is the lowest acceleration and 255 is the highest. 0 turns off acceleration. Turning on acceleration helps to increase position repeatability.

d x Set deceleration.

Parameter x:

Integer number in range of from 0 to 255. 1 is the lowest deceleration and 255 is the highest. 0 turns off deceleration. Turning on deceleration helps to increase position repeatability.

s x Set maximal motor speed.

Parameter x:

Integer number in range of from 1 to 65000. Polarizer Rotator waveplate rotation angular speed can be calculated using such formula:

$$\omega = \frac{14400000}{78r(65535 - x)};$$

Here ω – angular waveplate rotation speed (degrees per second), r – micro stepping resolution – 1, 2, 4, 8 or 16.

Controller advances motor per one step in time intervals equal to: $T=(65535-x)/8 \mu s$

p Shows controller settings, related to “Command” mode. Type this command only when using terminal and manual command entering. This is the way to see fundamental settings in “eye friendly” fashion. To get controller settings for software programming, use “pc” command instead. This command can be used to “ping” controller (to check if controller is attached to particular COM port). If device response to “p\r” string begins with “pUSB:“, it means that Polarizer Rotator is attached and is turned on.

Return string (finished with 0x0A and 0x0D symbols):

USB: [1] a=[2] d=[3] s=[4] wm=[5] ws=[6] wt=[7] r=[8]
en:[9] zr:[10] zs:[11]

- [1] Boolean 1 or 0. Current operating mode: “Command” mode if 1, and “Step-Dir” mode if 0;
- [2] Integer 0..255. Acceleration value;
- [3] Integer 0..255. Deceleration value;
- [4] Integer 1..65500. Speed value;
- [5] Integer 0..255. Motor motion current value;
- [6] Integer 0..255. Motor idle current value;
- [7] Integer 0..255. Motor current value in “Step-Dir” mode;
- [8] Integer 1, 2, 4, 8 or 6. Micro stepping resolution value (full, half, quarter, eight or sixteen);
- [9] Boolean 1 or 0. Motor enable: motor is enabled if 1 and motor is disconnected if 0;
- [10] Boolean 1 or 0. Whether to report coordinate then hitting zero position switch (if 1) or do not report (if 0). If this option is on (1), controller sends string “zp: [integer_position]” on each zero position button press;
- [11] Boolean 1 or 0. Whether to reset position counter on each zero position switch press or no. If this option is disabled (0), zero position button press does nothing to step counter. If waveplate holder is turned twice, command “o” will show us that position is more than 15600 (15600 is full waveplate turn in full stepping mode).

If this position is enabled (1), position counter will become 0 on each zero position switch press.

Response example (default controller settings):

USB: 1 a=232 d=232 s=55000 wm=114 ws=36
wt=114 r=2 en:1 zr:0 zs:0

pt Show controller settings, related to “Step-Dir” mode. Type this command only when using terminal and manual command entering. This is the way to see settings in “eye friendly” fashion. To get controller settings for software programming, use “pc” command instead.

Return string (finished with 0x0A and 0x0D symbols):
swEn:[1] en:[2] swDir:[3] dir:[4] zr:[5] zs:[6] cs:[7]

All returned parameters are boolean: 0 or 1.

[1] Boolean 1 or 0. Status of switch SW E (see Figure 5). 1 means that “Enable” pin is disconnected and motor is enabled if [2] parameter is 1 or disabled if [2] is equal to 0. If [1] is 0, then controller output state is dependent on logic level on “Enable” input;

[2] Boolean 1 or 0. Motor enable: motor is enabled if 1 and motor is disconnected if 0. This setting is meaningful if parameter [1] is On;

[3] Boolean 1 or 0. Status of switch SW F (see Figure 5). 1 means that “Dir” pin is disconnected and motor turns clockwise if [4] parameter is 1 or counterclockwise if [4] is equal to 0. If [3] is 0, then motor direction is dependent on logic level on “Dir” input;

[4] Boolean 1 or 0. Motor direction: motor turns clockwise if [4] parameter is 1 or counterclockwise if [4] is equal to 0. This setting is meaningful if parameter [3] is On;

[5] Reserved;

[6] Reserved;

[7] Reserved;

Response example (default controller settings):
swEn:0 en:1 swDir:0 dir:1 zr:0 zs:0 cs:0

pc Show all controller settings, separated by semicolon (;). Use this command when programming computer software to read all settings.

Return string (finished with 0x0A and 0x0D symbols):
[1];[2];[3];[4];[5];[6];[7];[8];[9];[10];[11];[12];[13];[14];[15];[16];[17];[18];[19];[20];[21];[22];[23];[24];

Character meaning:

[1] Boolean 1 or 0. Current operating mode: “Command” mode if 1, and “Step-Dir” mode if 0;

[2] Integer 0, 1, 2 or 3. Current motor run state: 0 – motor is stopped, 1 – accelerating, 2 – decelerating 3 – running at constant speed;

[3] Integer from 0 to 255. Acceleration value;

[4] Integer from 0 to 255. Deceleration value;

[5] Integer from 1 to 65500. Speed value;

[6] Integer from 0 to 255. Motor motion current value. $I = 0.00835x$ (A);

[7] Integer from 0 to 255. Motor idle current value. $I = 0.00835x$ (A);

[8] Integer from 0 to 255. Motor current value in “Step-Dir” mode. $I = 0.00835x$ (A);

[9] Integer 1, 2, 4, 8 or 6. Micro stepping resolution value (full, half, quarter, eight or sixteen);

[10] Boolean 1 or 0. Motor enable: motor is enabled if 1 and motor is disconnected if 0;

[11] Reserved;

[12] Boolean 1 or 0. Whether to reset position counter on each zero position switch press or no. If this option is disabled (0), zero position button press does nothing to step counter. If waveplate holder turned twice, command “o” will show us that position is more than 15600 (15600 is full waveplate turn in full stepping mode). If this position is enabled (1), position counter will become 0 on each zero position switch press;

- [13] Boolean 1 or 0. Whether to report coordinate then hitting zero position switch (if 1) or do not report (if 0). If this option is on (1), controller sends string “zp: [integer_position]” on each zero position button press;
 - [14] Reserved;
 - [15] Reserved;
 - [16] Reserved;
 - [17] Boolean 1 or 0. Motor direction setting in “Step-Dir” mode: motor turns clockwise if [17] parameter is 1 or counterclockwise if [17] is equal to 0. This setting is meaningful if parameter [20] is On;
 - [18] Boolean 1 or 0. Motor enablesetting in “Step-Dir” mode: motor is enabled if 1 and motor is disconnected if 0. This setting is meaningful if parameter [1] is On;
 - [19] Reserved;
 - [20] Boolean 1 or 0. Status of switch SW F (see Figure 17). 1 means that “Dir” pin is disconnected and motor turns clockwise if [17] parameter is 1 or counterclockwise if [17] is equal to 0. If [20] is 0, then motor direction is dependent on logic level on “Dir” input;
 - [21] Boolean 1 or 0. Status of switch SW E (see Figure 17). 1 means that “Enable” pin is disconnected and motor is enabled if [18] parameter is 1 or disabled if [18] is equal to 0. If [21] is 0, then controller output state is dependent on logic level on “Enable” input;
 - [22] Reserved;
 - [23] Reserved;
 - [24] Reserved.
- Response example (default controller settings):**
1;0;232;232;55000;114;36;114;2;1;1;0;0;1;0;1;1;1;0;0;0;0;1;
-

- o Return running state of the motor and current position.
Return string (finished with 0x0A and 0x0D symbols):
[1];[2]
[1] Integer 0, 1, 2 or 3. Current motor run state:
0 – motor is stopped, 1 – accelerating, 2 – decelerating 3 – running at constant speed;
[2] Integer in range of -2147483646..+2147483646. Current motor position;
Response example:
3;4437
Use this command to determine if motor has done its movement. After issuing any move command, poll “o” command in time intervals about 250 ms and decode response. If [1] parameter become 0, it means that motor has stopped and is ready for next move command.

- zr x** Report zero position when hitting zero position switch.
Parameter x:
1 Controller sends string “zp: [integer_value]” on each zero position button press;
0 Turn off zero position reporting.

- zs x** Reset coordinate counter then hitting hardware zero position switch.
Parameter x:
1 Position counter will become 0 on each zero position switch press;
0 Position counter increases position continuously.

- en x** Motor enable in “Command” mode.
Parameter x:
1 Motor is enabled.
0 Motor is disconnected.

j Reset controller.

Controller resets in 4 s after issuing this command. It is equivalent to power switch press. This command can also enter into firmware upgrade mode if firmware upgrade button is pressed. All changed settings and position are restored in previous state, if “ss” and/or “so” commands was not issued before reset.

Then controller starts, it sends string “STEP/DIR mode” or “USB mode” according to state of pin “ModeSel”.

a 0 Turn off acceleration.

d 0 Turn off deceleration.

ss Save settings of controller.

Save configuration mentioned in “pc” command description to controller memory. Configuration saved by “ss” command will be restored on controller power on.

sn x Write 20 character long name to controller

Parameter x:

20 characters. If x is not 20 symbols, then returned name can consist of unreadable characters. Please space pad trailing name.

n Show name.

Returns 20 character string, saved by “sn” command.

Return: 20 character string

4.5. Serial command usage with National Instruments “LabView”

There are plenty of applications built for serial port communication. Windows XP (and full installations of Windows 7 or Windows 8) has native “hypertrm.exe” terminal application, which can be launched by typing “hepertrm” in “Run” dialog (Winkey + R). Linux and OS X users can use free “CuteCom” (<http://cutecom.sourceforge.net>) utility, see Figure 14 on page 27.

For Windows OS it is recommended to use free tool “terminal.exe” from <https://sites.google.com/site/terminalbpp> Figure 15 on page 34.

Configure “terminal.exe” as follows:

1. Select correct com port number (see “Identifying serial port name” on page 27);
2. Select correct serial port configuration values (see Table 6 on page 26);
3. Set “Hex” checkbox if received characters should also be shown as hexadecimal values;
4. Click “Connect” button;
5. Type in command and press “Enter” key on keyboard. Command string “p\r” is sent to device as shown in example picture. Look at “Serial commands and protocol” on page 27 for available commands;
6. Polarizer Rotator response is shown in middle pane. Hex representation of all received bytes is shown on the right. Controller “speed” setting is set to “55000” as seen in example screenshot.

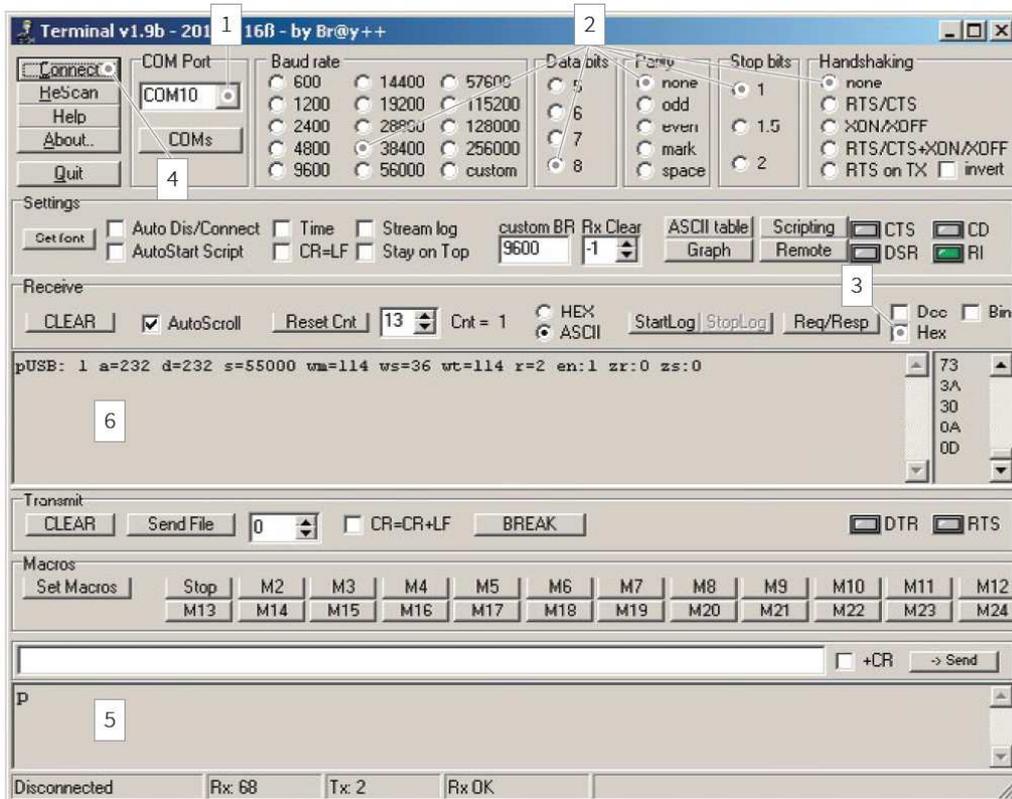


Figure 15. “terminal.exe” window with “p” command sent.

Presets can be configured for frequently used commands. Click “Set Macros” button, “Macro Settings” window will appear.

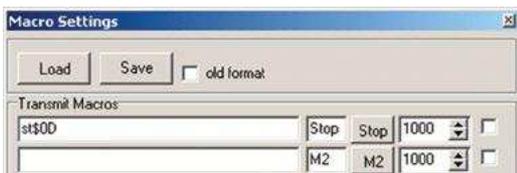


Figure 16. Command string presets can be configured by clicking “Set Macros” button in main “terminal.exe” window.

Type in string which should be sent, and name of this preset. Hexadecimal values can be entered with “\$” prefix. For example command end symbol “\r” [0x0D] should be entered as “\$0D”. “Stop” command definition is shown in example. Click “Save” button to save your presets. “Stop” button will appear in “Macros pane” of main window. Press it to stop attenuator motor motion.

4.6. Serial command usage with National Instruments “LabView”

There is a „Serial port“ control in LabView. Add it to your LabView project and set its properties to parameters listed in “Table 6” on page 26. Then use commands described in “Serial commands and protocol” (on page 27) to control motor: use „g xx“, „m xx“ commands for moving, and „o“ command for checking if motor has stopped. To calculate motor step position for required laser power, use formulas, shown in chapter “Relation between motor position and laser power” on page 35.

4.7. Relation between motor position and laser power

Transmitted laser power ratio can be in range of 0.0 (max attenuation) to 1.0 (min attenuation). According to Malus' law, waveplate angle ϕ can be calculated from "ratio": $\phi = \cos^{-1}(\sqrt{\text{ratio}})$ (degrees). In order to get motor step position "steps" from waveplate rotator angle ϕ , use relation $\text{steps} = \phi \cdot k \cdot r$, where coefficient "k" is "steps per unit", depending on waveplate rotator. $k = 43.333$ steps/deg for standard attenuator, and $k = 100.0$ for big aperture attenuator; coefficient "r" is controller's resolution parameter, it must be read from controller using "p" command", or got in "Polarizer Rotator" software "Options → Motor Settings → Advanced...". "r" can be 1, 2 (default), 4, 8, 16 (microsteps per step). So motor step position "steps", using standard attenuator with default (unchanged from purchase) settings, can be calculated as:

$$\text{steps} = \cos^{-1}(\sqrt{\text{ratio}}) \cdot 43.333 \cdot 2,$$

where "ratio" is required transmission (0.0 .. 1.0), "43.333" is "step per degree" for standard attenuator, and "2" is default resolution multiplier.

Usually arccosine function (acos()), found in programming packages operates with radians, so degrees must be converted to radians. Real relation between "ratio" and "steps", used in "Polarizer Rotator" software is calculated using following C# methods:

```
// Returns step position to be passed to "g steps" command.
```

```
// ratio – double in range 0.0 to 1.0.
```

```
public Int32 GetStepPositionFromRatio(double ratio)
```

```
{
```

```
return GetStepPositionFromDegrees(GetAngleFromRatio(ratio));
```

```
}
```

```
// stepsPerUnit: 43.333 for standard attenuator or 100.0d for Big aperture attenuator.
```

```
// resolution: 1.0d, 2.0d, 4.0d, 8.0d, 16.0d, depending on controller settings.
```

```
public Int32 GetStepPositionFromDegrees(double degrees)
```

```
{
```

```
double steps = degrees * stepsPerUnit * resolution;  
return (Int32)steps;
```

```
}
```

```
// converts ratio (0.0..1.0) to waveplate angle in degrees.
```

```
// ratio – double in range 0.0 to 1.0.
```

```
public double GetAngleFromRatio(double ratio)
```

```
{
```

```
double angle = ((Math.Acos(Math.Sqrt(ratio))) * 180.0) / (2.0 * Math.PI);
```

```
return angle;
```

```
}
```

Angular offset between waveplate and waveplate rotator is important, so "degrees" parameter in GetStepPositionFromDegrees (double degrees) should be adjusted accordingly to offset, before passing.

5. Troubleshooting

5.1. Real laser power does not match shown in software

Click “Home” button in Polarizer Rotator “Control” window. This eliminates angular error, which can occur if power is lost during waveplate motion.

5.2. “Upgrade controller firmware now?” message appears

Once connected, Polarizer Rotator software checks firmware version on device, and updates it if necessary. Progress bar will popup informing user that firmware update is in progress and one must wait until flashing process is finished.



Figure 17. Normal firmware update process finish is indicated by “Firmware upgrade complete” message.

It will take up to one minute and requires user not to disturb update process. The process is not cancellable. Do not disconnect USB or power supply cables, do not shutdown the computer. This window can appear after “Polarizer Rotator” software is updated, because latest firmware comes with Polarizer Rotator installer file. Confirmation message will appear after update is completed, click “OK” and program will continue as usual. If firmware upgrade window is different than shown here, see “Troubleshooting” chapter on page 38.



Figure 18. Dialog, asking whether to update firmware.

This will appear if controller firmware cannot be updated without user interaction and depends only on controller firmware version, not related to hardware revision. It will pop up if controller has firmware version prior to v8, released on August 22, 2012. These dialogs will never show up again once firmware is updated.

Warning!

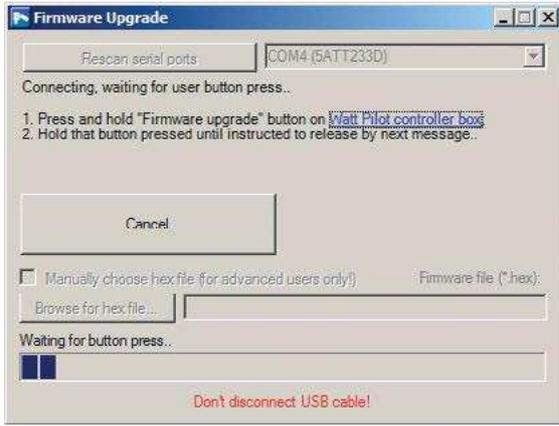
Upgrade process cannot be interrupted! Do not disconnect USB, attenuator or power supply cables, do not shutdown the computer. Do not use other devices while flashing. If upgrade is interrupted or unsuccessful, go to the end of this troubleshooter point to recover

Follow these steps to update firmware manually:

1. Answer “Yes” when asked about update dialog is shown in Figure 18. “Firmware Upgrade” window will appear. Click “Upgrade Firmware” button:



2. Progress bar on lower part of the window begins to fill, now program is waiting for user to press “Firmware upgrade” button, which is located inside controller box. Proceed to next step.



3. Press and hold firmware upgrade button located under small hole on controller's front panel. This must be done in one minute, otherwise process must be restarted. Firmware upgrade button is marked by yellow arrow in the picture below. It can be accessed with teeth stick, for example.



Figure 19. "Firmware upgrade" button location inside Polarizer Rotator controller.

4. Hold "Firmware upgrade" button pressed until confirmation about release will be displayed in "Firmware Upgrade" window as shown below. Usually button must be held pressed up to 15 seconds. Process status is displayed above progress bar.



5. Now wait till "Firmware upgrade was successful!" message appears. It will take up to 1 minute to complete.



6. Click "OK" in "Firmware upgrade complete" message box. "Firmware Upgrade" window will close and "Polarizer Rotator control" window will start.

5.3. Firmware upgrade was unsuccessful or interrupted

In case firmware upgrade ended unsuccessfully due to some reasons (cable disconnection, program crash...), usually such error will be thrown then trying to use Polarizer Rotator.



Figure 20. Error, thrown if device firmware becomes corrupted.

In order to recover, follow these steps:

1. Close “Polarizer Rotator” software;
2. Turn off controller using “ON/OFF” switch:



3. Press and hold down “Firmware upgrade” button located inside controller box, see Figure 19 on page 39 to find there it is;
4. Turn on controller, while holding firmware upgrade button pressed;
5. Release button after 10 second after power on;

6. Launch “Polarizer Rotator” software and try to use the device;
7. Firmware will be correctly rewritten automatically. Device will be ready to use after one minute.

6. List of Tables

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