Watt Pilot Motorized Attenuator

User Manual

Altechna

Contents

Watt Pilot

February 2015

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2. The serial number of the product is defaced or missing.

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1. Introduction

This user manual is designed to help to install and operate Watt Pilot. Before installing and operating Watt Pilot please read installation and operation instructions carefully. Safety instructions must be read carefully. 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. Watt Pilot short description

Motorized Watt Pilot is a computer controlled laser beam attenuation device. It attenuates free space laser beam/pulse continuously without introducing additional energy fluctuations. Watt Pilot is controlled by computer via USB. Also it has "STEP/DIR INTERFACE" connector for controlling via other devices.

1.2. General safety requirements

Motorized Watt Pilot is designed to operate in conjunction with a laser system. All applicable rules and regulations for safe operation of lasers must be known and applied while installing and operating Watt Pilot. The customer is solely responsible for laser safety while using Watt Pilot as a standalone device or integrated into a system. The customer must consider protective measures.

While assembling or operating Watt Pilot, 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 the laser beam through Watt Pilot, laser power must be kept as low as possible. Hazardous laser radiation can increase while optical components or instruments are used in combination with Watt Pilot. Appropriate eye protection must be worn at all times. Electrical safety requirements must be complied while assembling and operating Watt Pilot.

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 Watt Pilot 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.

- Watt Pilot must be protected from humidity, dust and corrosive vapors to avoid damaging optical components and electronics.

- Avoid strong static electricity and electromagnetic fields.

2. Operation Principle

The motorized Watt Pilot incorporates a rotating quartz **λ**/2 phase waveplate and one or two polarizers which separate s-polarized and p-polarized beams. The intensity ratio of the two beams may be continuously varied without alteration of other beam parameters by rotating the waveplate The intensity ratio of these two beams is continuously tuned by rotating the waveplate. Proper functioning of Watt Pilot requires optimal configuration of optical elements related to the polarization contrast of the incident laser beam. Higher incident laser beam polarization contrast leads to higher Watt Pilot output polarization contrast.

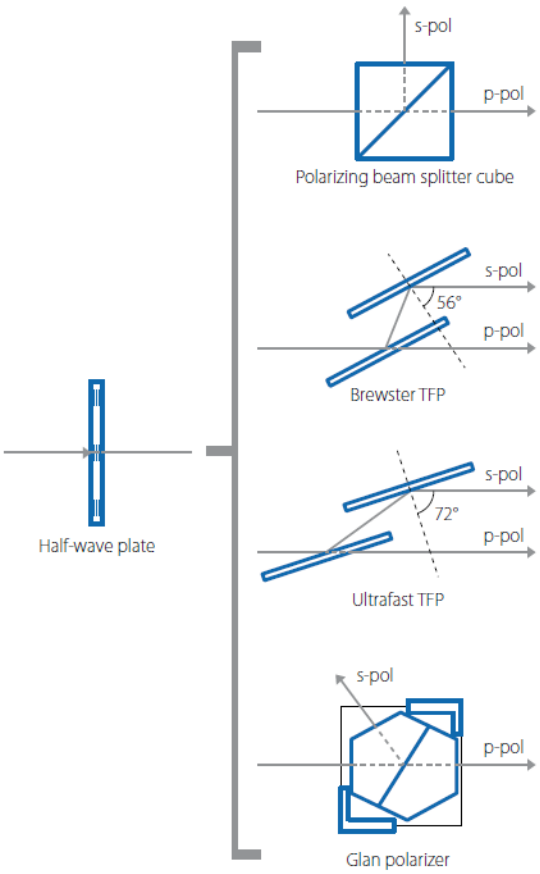


Figure 1. Various configurations of Watt pilot, illustrating operation principle.

3. Package contents

- Motorized polarizer rotator:
- Controller
- USB cable (2m length recomended but no longer than 3m)
- 12V power supply
- Software, installation instructions in USB flash
- Two waveplate retaining rings and tightening wrench
- Polarizer holder
- Polarizer(s) – (might be already in the holder)
- Wavepalte

3.2. Optics assembling

Watt pilot assembly instructions can be found below. Every watt pilot version (Standard, Enhanced and Ultrafast) is slightly different and this should be tanken into accont when assembling.

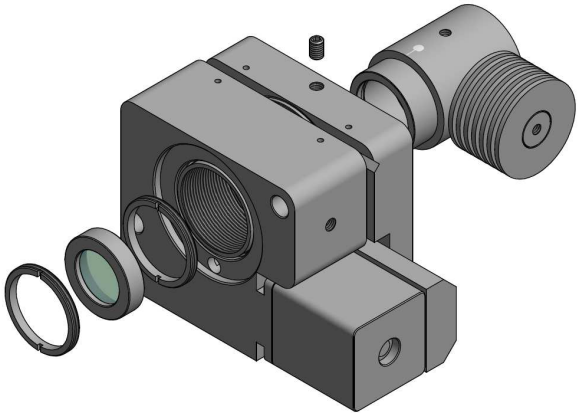


Figure 2. Watt Pilot standard version assembly.

Step 1. Put wave plate into attenuator between two mounting rings as shown. Be sure the wave plate is immobilized tightly.

Step 2. Use a fixing screw for tightening the rotator part and polarizer holder together (polarizing cube is already in the holder).

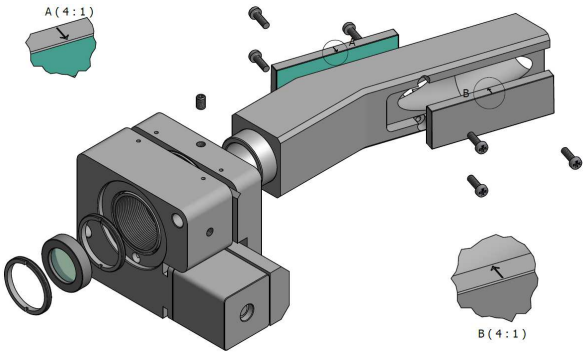


Figure 3. Watt Pilot Ultrafast version assembly.

Step 1. Put wave plate into the attenuator between two mounting rings as shown. Be sure the wave plate is immobilized tightly.

Step 2. Place polarizer into mechanical adapter. Engraved arrows, on the polarizers indicate coated surface, they must point towards the mount. Before assembling one should make sure, that both arrows are seen from the top. Then polarizer should be fixed with the plastic bolts (use all 3 plastic bolts to fix polarizer).

Step 3. Use fixing screw for tightening rotator part and polarizer holder together.

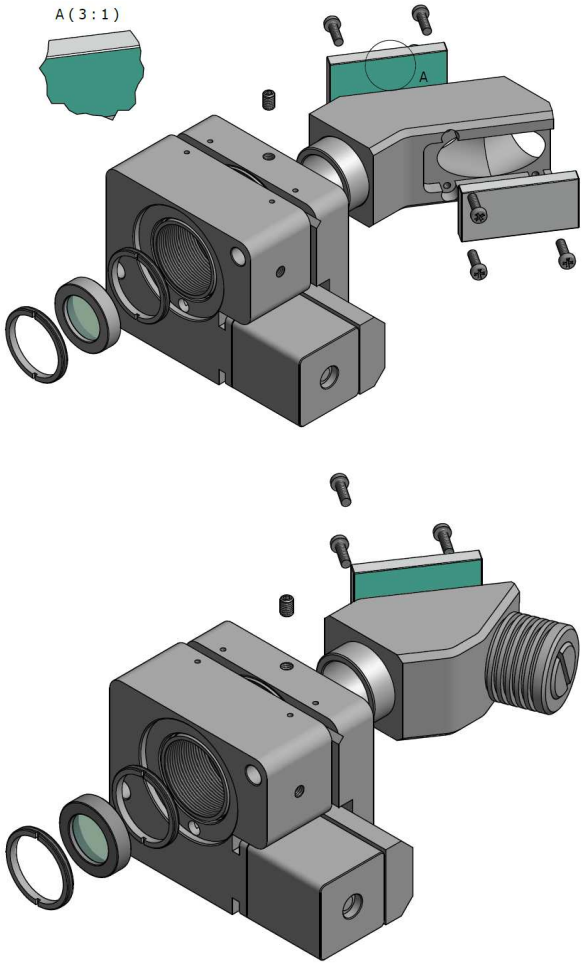


Figure 4. Watt Pilot Enhanced version assembly.

Step 1. Put the wave plate into the attenuator between two mounting rings as shown. Be sure the wave plate is immobilized tightly.

Step 2. Place polarizer into the mechanical adapter. The polarizer‘s coated surface must face the holder. Then the polarizer should be fixed with plastic bolts (use all 3 plastic bolts to fix the polarizer).

Step 3. Use a fixing screw for tightening the rotator part and polarizer holder together.

Note

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

Note

Do not tighten up the bolts too much - it can bend the polarizer and thus distort the laser beam.

4. Watt Pilot Software Description

4.1. Computer requirements

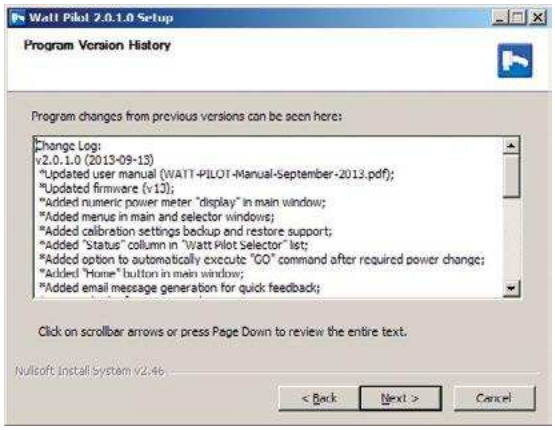
- Free USB port. Watt Pilot is compatible with USB 1.1, USB 2.0 and USB 3.0. Computer administrator rights (only for installation)
- Windows XP sp3 (32-bit)
- Windows Server 2003 sp2 (32-bit)
- Windows Vista sp1 (32/64-bit)
- Windows Server 2008 (32/64-bit)
- Windows 7(32/64-bit)
- Windows 8(32/64-bit)
- Microsoft.Net framework 4.0 redistributable (installs automatically)

4.2. Software installation

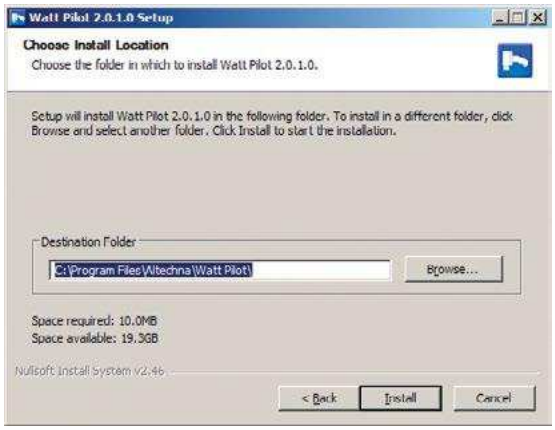
1. Check for and download the latest “Watt Pilot” software installer package from www.altechna.com/product_details.php?id=824.
2. Run the downloaded “Watt Pilot-Setup.exe” installation file. In case you are installing on an operating system that does not meet requirements, only USB drivers will be installed. Click “Yes” to continue.

3. Installation window will appear, click “Next” to continue:

4. Click “Next”:

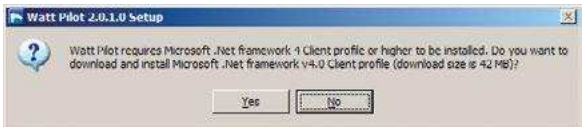


5. Select installation directory and click “Next” to begin installation:

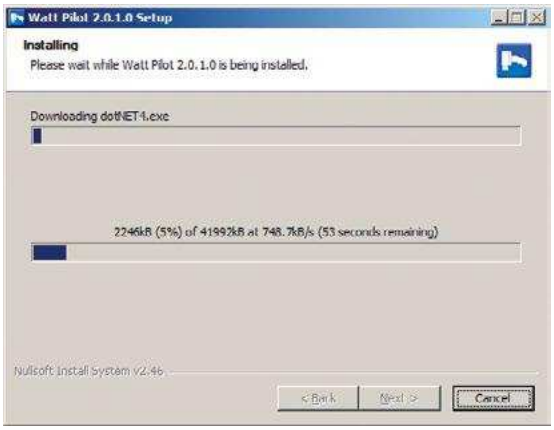


6. “Watt Pilot” software requires “Microsoft.NET Framework 4 Client Profile” or higher version to be installed. Setup will offer to download it, choose “Yes” if you have active internet connection. Choose “No” to download it from www.microsoft.com/en-us/download/details.aspx?id=17113 and install it manually. You should choose “No” if you wish to install any newer version of framework, or do not have a working internet connection. This dialog will not

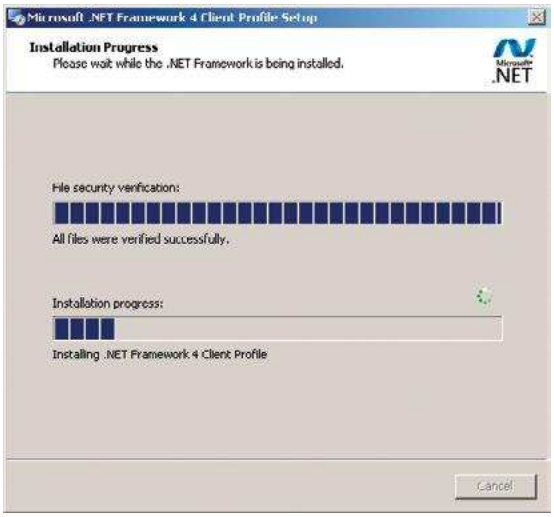
appear if framework is already installed. Download size is 42 Mbytes.



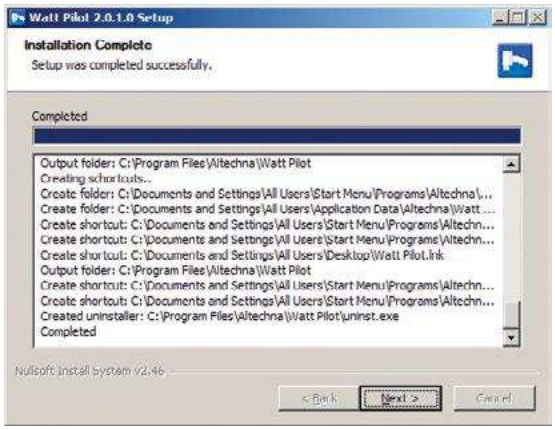
7. Setup will download “Microsoft .NET Framework 4 Client Profile”.



8. After the download is finished, “Microsoft .NET Framework 4 Client Profile” will be installed, wait for it to complete. This can take more than 10 minutes on a slower machine.



9. Setup will finish by installing drivers. Click “Next” to continue:“



10. Click “Finish” to end installation. The program cannot be opened if only drivers were installed (see step 2 for details).

11. “Watt Pilot” software icon will appear on “All Users” desktop and “All Users” start menu.

12. Connect rotator to Watt Pilot controller.

13. Connect Watt Pilot and PC via a USB cable.

14. Turn power switch on the controller to „ON“

15. Plug in Watt Pilot power supply jack and AC adaptor to wall outlet.

16. Windows will detect new hardware. Wait until windows configures new device.

4.3. Program first run

Launch “Watt Pilot” program using “Watt Pilot” icon on desktop or from “Start Menu → All Programs → Altechna → Watt Pilot → Watt Pilot”. Watt Pilot “Selector” window will appear. At least one device must be displayed on the list. If the list is empty, please check the USB cable, power connection and “ON/OFF” switch – it must be in “ON” position. Green LED near power switch must be active if power is OK. Click “File → Search For Devices” to refresh. For more information about Watt Pilot “Selector” window see section”

Watt Pilot “Selector” window” on page 11.

Select Watt Pilot from a list and click “File → Connect”. Program will update controller firmware if necessary. Usually this process is automatic and does not require any action, just wait until “Firmware upgrade was successful!” message appears. If problems arise with the firmware update, see “Firmware update” on page 17 and “TROUBLESHOOTING” on page 38.

Once connected to Watt Pilot, dialog will pop up informing that no calibration file is found for new attenuator:

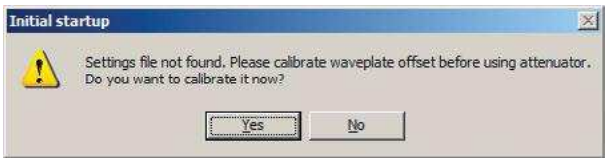


Figure 5. Dialog box, shown if Watt Pilot calibration file is not found.

Select “Yes”, calibration window will appear. Use instructions in section “Calibration” on page 12 to setup calibration. After calibration is done, “Watt Pilot control” window will appear. Use slider to select and set required power. See section “Watt Pilot “Control”window” window on page 13 if more information is needed.

4.4. Watt Pilot “Selector” window

Watt Pilot “Selector” window contains a list of currently connected and powered attenuators. This window is used to choose the device to work with if there are several controllers connected to a single computer. Double click on the device name you want to select. Functions of this window are described in the picture below.

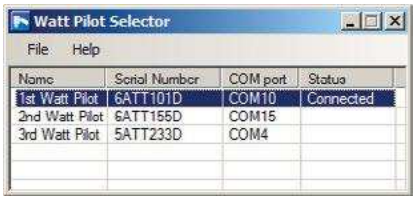


Figure 6. Watt Pilot “Selector“ window. It is displayed every time program is started. There are three devices attached to the PC in the shown screenshot. Double click the listed attenuator to open control window for it.

Column description:

- Name

  It is useful to give meaningful titles for each Watt Pilot, if more than one is used in the same system. For example, name can be set to “1st Harmonic WP”, and another attenuator can be named as “2nd Harmonic WP”. New name is saved into controller’s internal memory, so new name will be maintained on any computer. Name length is restricted to 20 characters maximum. Watt Pilot can be renamed from “Watt Pilot control” window “Options->Watt Pilot Name...” menu option.

- Serial Number

  This column shows unique Watt Pilot controller hardware serial number. It is used to identify hardware at low level. Serial number must be used for hardware identification when contacting the developers.

- COM port

  Each Watt Pilot gets unique serial port name after first enumeration with computer. This column shows USB-serial port name assigned by Windows. COM port name is necessary to know for advanced users who want to use serial commands in their applications. See chapter “Serial commands and protocol” on page 27 for more details about this.

- Status

  This column shows “Connected” if attenuator control window is active. Otherwise it is blank.

“File” menu description:

- Connect

  Opens control window for selected Watt Pilot, (the same effect as double-click on the device in the list. If only one device is connected during program startup, the control window will be opened automatically. See chapter “Watt Pilot Control” window” on page 13 for information.

- Search For Devices

  Starts searching for Watt Pilot devices attached to computer. It can help if not all devices are detected and listed automatically.

- Close

  Closes Watt Pilot “Selector” window, but leaves control windows opened.

- Exit

  Closes Watt Pilot “Selector” and all control windows.

“Help” menu description:

- User Manual

  Opens user manual

- About

  Shows software version and contact information.

4.5. Calibration

In order to correctly change the output power, the software needs to know λ/2 waveplate’s fast axis angle. It can be fixed in any angle with respect to the rotator. The purpose of calibration is to fix the angular offset between the λ/2 waveplate and the rotator hardware zero position. The calibration window is opened automatically on first use of Watt Pilot, or can be found in menu “Options → Calibration…” in “Watt Pilot control” window. Make sure that the attenuator is correctly aligned before calibrating.

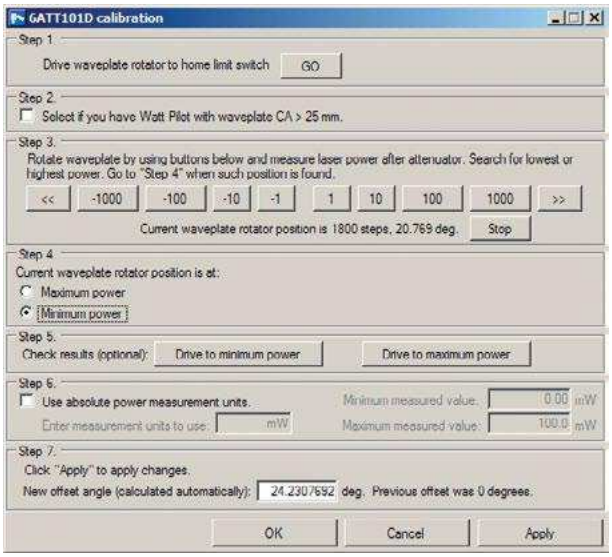


Figure 7. Calibration window.

Calibration procedure:

1. Homing. Click “GO” button in section “Step 1” and wait till motor stops. This will drive the waveplate holder to the hardware limit switch (zero position). Step 1 must be performed every time the device is turned on or after extensive period of usage to eliminate any accumulated position error.

2. Check checkbox in “Step 2” if using “Big aperture” waveplate rotator. See pictures below

Standard rotator. “Step 2” check-box must be unchecked

“Big aperture” rotator. “Step 2” check-box must be checked

Figure 8. Standard and “Big aperture” waveplate rotators.

3. Rotate waveplate by using buttons in section “Step 3”, and measure laser power after the attenuator. Numbers on the buttons represent motor moving distance (expressed in stepper motor steps) and rotation direction. One step equals 0.0115 degrees for

standard waveplate rotator and 0.005 degrees for big aperture attenuator using default settings.

Note

It is advised to search for lowest power (max attenuation) position, because usually it can be spotted more easily and accurately.

4. Send minimum or maximum signal power and select the appropriate option in “Step 4”. It will be called “Home position” in the control window. Angular offset is recalculated and shown in “Step 7” field every time “Step 4” selection is clicked. At this moment, main calibration goal is completed and “Apply” button can be clicked to apply changes. Further steps are not mandatory, but should be considered for convenience.

5. The calibration result can be verified by using buttons in the “Step 5” panel. Usage example: click “Drive to minimum power” button and wait till rotator stops. Use buttons “-10” and “10” (located in “Step 2”) to ensure if current position is really of lowest power. If it is, click “Apply”, else select “Minimum power” in “Step 4” again, to redefine offset. The same can be done with maximum power point.

6. Alignment of polarizers and waveplate is critical for ensuring optimal performance, thus during the calibration Watt Pilot should be aligned to reach maximum performance. Real maximal and minimal transmitted power should be obtained by adjuting polarizers with adjustment screws in the rotator. Once measured, these extreme values should be entered in relevant fields of “Step 6”. Usage example: one uses a 1 W laser, and 20 mW is measured as the minimal power, and 0.99 W as the maximum power. In such case, first “Use absolute power measurement units” should be checked, then a value of “0.02” should be entered into field “Minimum measured value:”, and “0.99” – into “Maximum measured value:”, and “W” should be enreted into “Enter measurement units to use:” textbox, because measurement units are “Watts”.

7. Click “OK” button to accept calibration or “Cancel” to discard. If dialog, window-request go to zero position will appear, click “Yes” for correct device operation.

4.6. Watt Pilot “Control” window

Watt Pilot “Control” window is used to change the laser power after the Watt Pilot attenuator. Main components of this window are described below.

- **Watt Pilot name and serial number** is shown on each attenuator control window caption. The serial number is unique for each Watt Pilot controller and cannot be changed as it is used to identify hardware at low level.

- **Power meter panel** always shows existing power after the attenuator. Percentage range is from 0 % to 100 % of transmission. Zero percent means that waveplate occurs at a 45 deggrees angle, beam polarization is rotated by 90 degrees and is maximally attenuated. Display reading “100%” means that waveplate is rotated at minimum attenuation – maximum transmission angle.

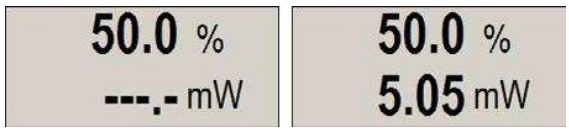


Figure 9. Power meter panel: right - “Use absolute power measurement units” checkbox is set in “Options → Preferences”, left - checkbox is unset.

If “Use absolute power measurement units” checkbox is set in “Options → Preferences” or during calibrating, numeric display, showing “mW” becomes active. Absolute power reading is converted from percentage value with respect to minimal and maximal measured power using a power meter. Correct min and max power values must be set in program preferences or calibration windows.

- **Lower slider** changes power from 0 % to 100 % with resolutuion of 0.25%. Values in lower numeric fields

will alter according to slider position. There is a triangle-shaped marker above the lower slider which shows current power setting, which serves as convenient reference for the slider usage.

- Enter required value (%) field is used to manually enter percentage of Watt Pilot transmission. Decimal point symbol is "." (dot), two decimal places can be used. Valid range is 0.00 % .. 100.00 %.
- Absolute required power field is available if "Use absolute power measurement units" option is set in "Options → Preferences…" or "Options → Calibration…". Decimal point symbol is "." (dot). Valid range is from "Minimum measured value" to "Maximum measured value" set in program preferences.
- Preset buttons can be used to quickly set discreet values of output power if absolute value was predefined in calibration stage.. Left click on any of them and appropriate value will appear in (4) or (5) text boxes.

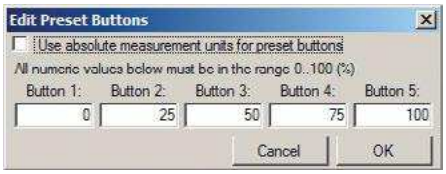


Figure 10. "Edit Preset Buttons" window. Currently preset values are 0%, 25%, 50%, 75%, 100% of transmission, because checkbox is unchecked. Otherwise all values would represent absolute power in user selected units.

"GO" button. Click to set power (rotate waveplate).

Note

If "Automatically execute "GO" after required power change" is selected in "Options → Preferences" waveplate would rotate automatically after any of aforedescribed power control option is used (button pressed, slide moved, power value enteres, etc. Otherwise click "GO" button to actually set power

- "STOP" button cancels rotation.
- Buttons "<<" and ">>" will continuously decrease/ increase power. Controller firmware must be up to date for these buttons to appear. If "Rotate continuous" option in program preferences is set, waveplate can be rotated to any angle, otherwise waveplate motion is restricted to 0.45 degrees.
- "Home" button will drive waveplate rotator to home limit switch and back to "Home position", set in "Options → Preferences…". Usually this should be executed every time when device is turned on.

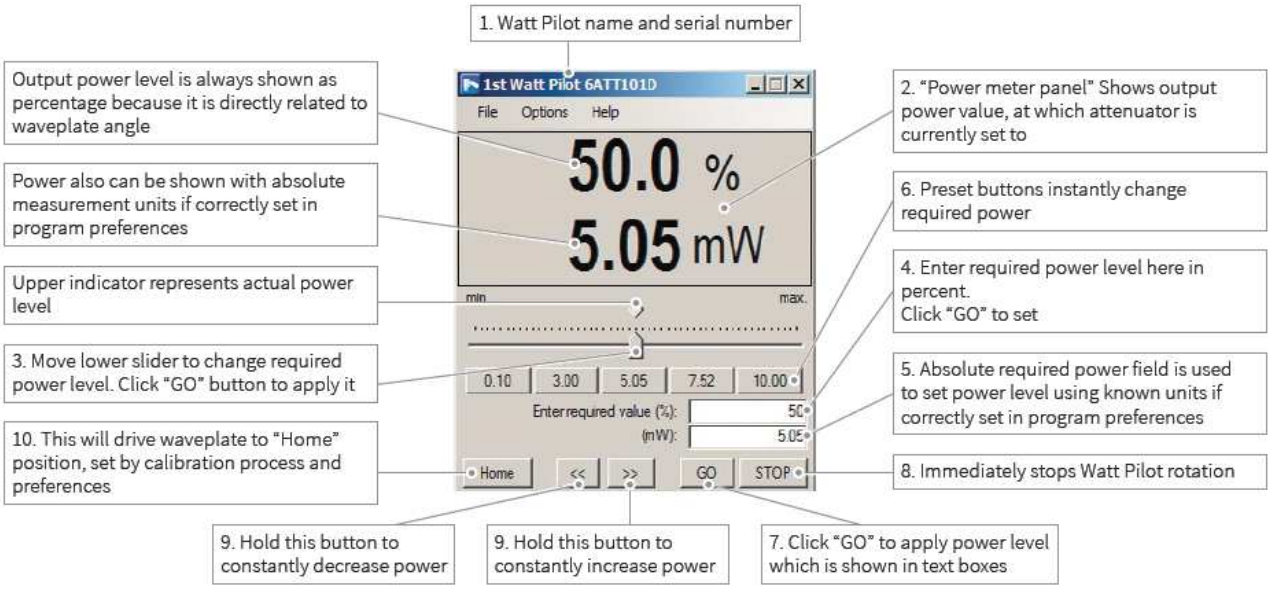


Figure 11. Watt Pilot "Control" window. Currently laser power is set to 5.05 mW or 50 % of full calibrated range. Measurement units are available because absolute minimal and maximal power values are set in program preferences during calibration process.

"File" menu description:

- Save Calibration…

Current program settings can be saved to file. Configuration file includes all options in "Options → Preferences", preset values and calibration offset. Run time program configuration files are saved in folder "Application data for all users*Altechna*\Watt Pilot\ Settings".

- Load Calibration…

Program settings can be restored from file. Configuration file includes all options in "Options → Preferences", preset values and calibration offset. Current configuration will be overwritten.

- Show Device Selector

Opens Watt Pilot "Selector" window.

- Close This Window

Disconnects from Watt Pilot and closes active "Control" window.

"Options" menu description:

- Calibration…

Opens Watt Pilot calibration window. See chapter "Calibration" on page 12 for details.

- Preferences

Opens program configuration window. See chapter "Program preferences description" on page 15 for details.

- Watt Pilot Name…
- Opens "Rename Device" window. Use up to 20 characters for name. Enter new name and click "OK" to accept.

Figure 12. "Rename Device" window.

"Motor Settings" submenu description:

- Set Safe Settings

This option sets waveplate rotator angular velocity to 8.73 deg/s, with acceleration and deceleration on. Such motor settings should be used if "Optimized settings" causes motor to stall or miss steps. Such problems may arise with old worn-out attenuators. Attenuation from 0 % to 100 % is changed in 7 seconds. These timings apply to "Standard" (not "Big aperture") rotator.

- Set Optimized Settings…

Sets waveplate rotator angular velocity to 14.076 deg/s, no acceleration and no deceleration. This is more faster motion than "Safe settings". Attenuation from 0% to 100% is changed in 3.19 seconds. Waveplate turns 360 degrees in 25.6 seconds. These timings apply to "Standard" (not "Big aperture") rotator. It is recommended to operate the attenuator with under "Optimized Settings" as it is designed for maximum performance withour sarcifise of reliability.

- Advanced…

Opens "Motor settings" window, where motor speed can be tweaked. It can be used for troubleshooting or to find best suted working point.

"Help" menu description:

- User Manual

Opens user manual.

- About…

Shows software version and contact information. Please include software version and controller serial number when contacting manufacturer.

4.7. Program preferences description

Preferences window can be accessed by "Options → Preferences" menu item in Watt Pilot control window.

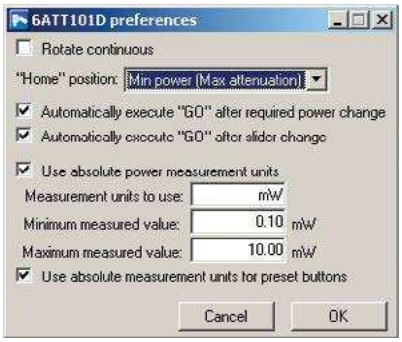


Figure 13. Program preferences window. Can be found under menu "Options → Preferences".

- **Rotate continuous.** If checked, waveplate could be rotated continuously using "<<" or ">>" buttons in control window. This would cause attenuation to switch between min and max attenuation 8 times in 360 degrees turn..
- **"Home" position.** Power can be set to max or min power after "Home" button clicked.
- **Automatically execute "GO" after required power change.** This allows waveplate to rotate right after the power value was changed by editing numeric fields' values in "Control" window.
- **Automatically execute "GO" after slider change.** This allows waveplate to rotate right after the power value was changed by moving the slide in "Control" window.

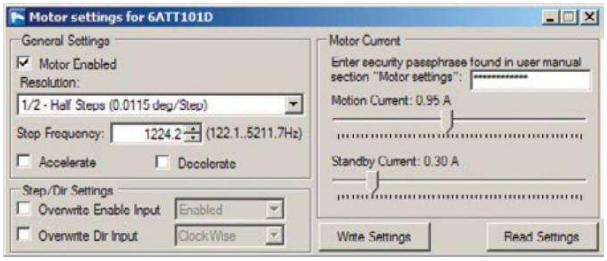
Note:

"Automatically execute "GO" after required power change" must be checked for this options to be enabled.

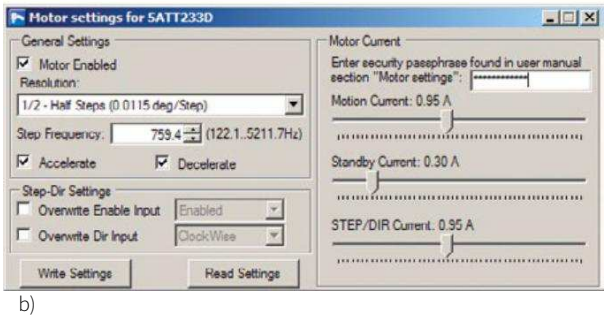
- **Use absolute power measurement units.** Setting this will enable power to be measured with absolute measurement units. Minimum and maximum power values must be known for this option to work. This setting can also be changed in "Calibration" window.
- **Measurement units to use.** Alphanumerical string can be entered here to represent measurement units. Default is "mW", but can be changed to "uW", if working with "micro watts".
- **Minimal and Maximal power meter reading.** These fields must be filled with minimal and maximal measured power values. Decimal separator symbol is dot (".."). These values will appear as available power range in main window.
- **Use absolute measurement units for preset buttons.** If this is set, preset button values are shown as absolute power values, otherwise, preset button values mean percentage (%) of transmitted power. Option "Use absolute power measurement units" must be set for this option to be enabled. Preset button values are recalculated automatically with respect to min and max measured power.

4.8. Motor settings description

Motor settings can be accessed from "Watt Pilot Control window" by "Options → Motor Settings → Advanced…". These settings are for advanced users only. Security passphrase for motor current controls is "I understand".



a)



b)

Figure 14. "Motor settings" window: a) Controller with latest firmware and serial number beginning with "5ATT" or "6ATT"; "Optimized" settings are applied. b) Controller with outdated firmware or serial number beginning "4ATT"; applied "Safe" settings. Passphrase "I understand" is entered in security field so motor current can be adjusted.

- Motor Enabled checkbox. If unchecked, no current flows through the motor windings. Default is checked.

- Resolution. Stepper motor can be driven in microstepping mode, so one motor step can be physically divided into 1 - no microstepping, 2 – half microstepping, 4, 8 or 16 microsteps. That means, that standard waveplate rotator could be set to resolution of 15600, 31200, 62400, 124800 or 2496000 steps per 360° turn. Big aperture waveplate holder could be set to 36000, 72000, 144000, 288000, 576000 steps per 360° turn. Running the motor in in full steps might cause resonance problems. The higher the resolution, the smoother and quieter motor operation is, but motor torque and speed would decrease with increased resolution. Half stepping resolution is used as default.

- Step frequency. Motors step frequency, thus waveplate angular velocity can be changed. Step frequency f [Hz] can have discrete vales such as=8000000/ (65535-n) , where “n“is integer in range of 1 .. 64000. Waveplate angular velocity **ω** [degrees/second] is equal to **ω**=360/(k·r). Parameter “k” is 15600 for standard attenuator, and 36000 for big aperture attenuator. Resolution divider “r” can be 1, 2, 4, 8 or 16, as mentioned earlier in “Resolution” description. “Safe” step frequency is 759.4 Hz, “optimized” step frequency is 1224.2 Hz, but it can be tweaked for best performance.

- Accelerate and Decelerate. If this option is set, motor gradually accelerates till maximum frequency is reached and decelerates before stopping. This can help to solve stall problems on worn out mechanics, but causes motion to last longer. These options should be unchecked for normal usage. Default is unchecked.

- Overwrite Enable Input option is used in “Step-Dir” mode only. If checked, voltage level on “Enable” pins 3 and 11 in DB15 connector are ignored, and motor is enabled or disabled depending on selection to the right.

Note:

Ask document “Watt Pilot User manual for advanced users” from supplier.

- Overwrite Dir Input option is used in “Step-Dir” mode only. If checked, voltage level on “Dir” pins 2 and 10 in DB15 connector are ignored, and motor direction is set depending on selection to the right.

Note:

Ask document “Watt Pilot User manual for advanced users” from supplier.

- Motor current settings. If motor current is set to higher value than default, it can cause permanent damage to motor or controller, so current changing sliders are disabled by default. In order to activate them, please enter string “I understand” (without quotes) in security text field. Motion current is used when motor rotates the waveplate, so it must be higher than standby current. Standby current is used when motor idles. Additional “STEP/DIR” current slider is present for controllers with serial numbers beginning with “4ATT” or newer controllers with outdated firmware version. This current drives motor continuously when controller operates in “Step-Dir” mode and motor is enabled by “Enable” signal on DB15 connector or by enable overwrite command. Motor current is cut off completely if enable signal is lost. In analogy with this, “Motion” and “Standby” current values are used for controllers with serial number “5ATT” or “6ATT”, so third slider is hidden. Third slider should be used only by advanced users and does not relate to watt pilot attenuator directly. Default motion current is 0.95 A for standard and for big aperture attenuators standby current is 0.3 A by default.

- Write settings button. Click this button to save configuration into controller’s memory. Currently

displayed settings will be reloaded after controller power cycle. If this button is not used, previously saved changes will be loaded after controller restarts.

- **Read settings button.** This will load configuration from controller.

4.9. Firmware update

Once connected, Watt Pilot 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 15. 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 "Watt Pilot" software is updated, because latest firmware comes with Watt Pilot 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.

5. Watt Pilot Controller Hardware

5.1. Controller specifications

Watt pilot controller is a 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	• Step Dir pulses • Computer software via USB port • Microcontroller via UART connection
Limit switch	One limit switch can be connected and used only for homing

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

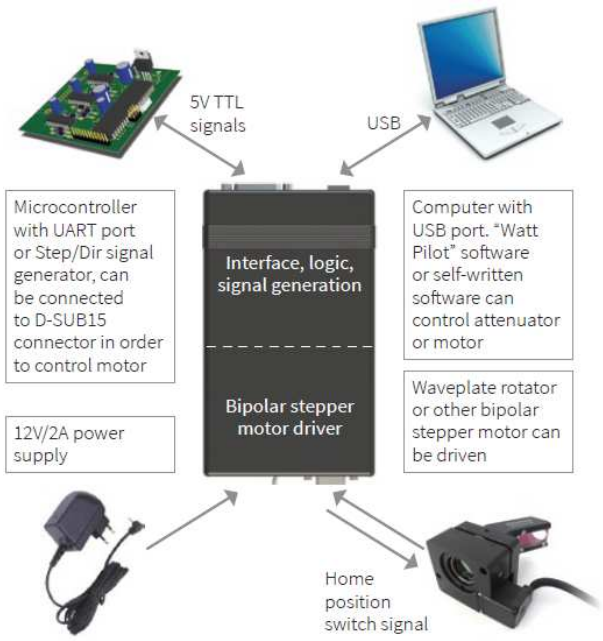


Figure 16. Illustration of Watt Pilotcontroller advanced features.

5.2. Controller connections

Watt Pilot front and rear connectors are shown in the pictures below.

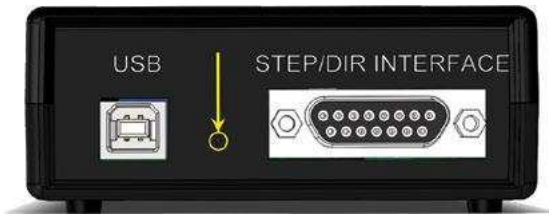


Figure 17. Controller front view.

- USB connector is used to control Watt Pilot with the computer.
- Firmware upgrade button is hidden under a small hole, highlighted by arrow. Use a needle to press the button if firmware upgrade process crashed. See "TROUBLESHOOTING" on page 38 if necessary.
- "STEP/DIR INTERFACE" connector can be used to control Watt Pilot with microcontroller via UART or "Sep-Dir" pulses. See section Operation modes: "Step-Dir" mode on page 20.

Figure 18. Controller rear view.

- Controller power supply socket. Plug dimensions: outer diameter - 5.5 mm (GND), central pin diameter - 2.1 mm (+12 V). Watt Pilot 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 Watt Pilot 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 Watt Pilot 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.

5.3. Controller internal block diagram

Watt Pilot controller consists of three blocks. Each is shown in Figure 20.

- Motor driver. This block drives the motor by controlling currents in the 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 the controller is working in "Command" mode.

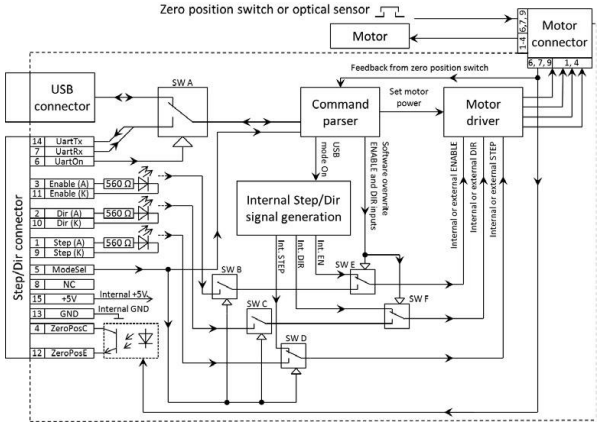


Figure 19. Block diagram of Watt Pilot controller.

5.4. 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. Watt Pilot appears as "virtual serial port" in computer device list when connected. "Watt Pilot" 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 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!

"Watt Pilot" 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.

5.5. Operation modes: "Step-Dir" mode

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

A 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 woth "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.

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

“STEP/DIR INTERFACE” connector is used to operate the 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 UartTx	UART baud rate 38 400, 8 data bits, 1 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 UartOn	These logic pins are 5V compatible with 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. The Watt Pilot 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 the motor shaft is inert. Frequency of the 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 20.

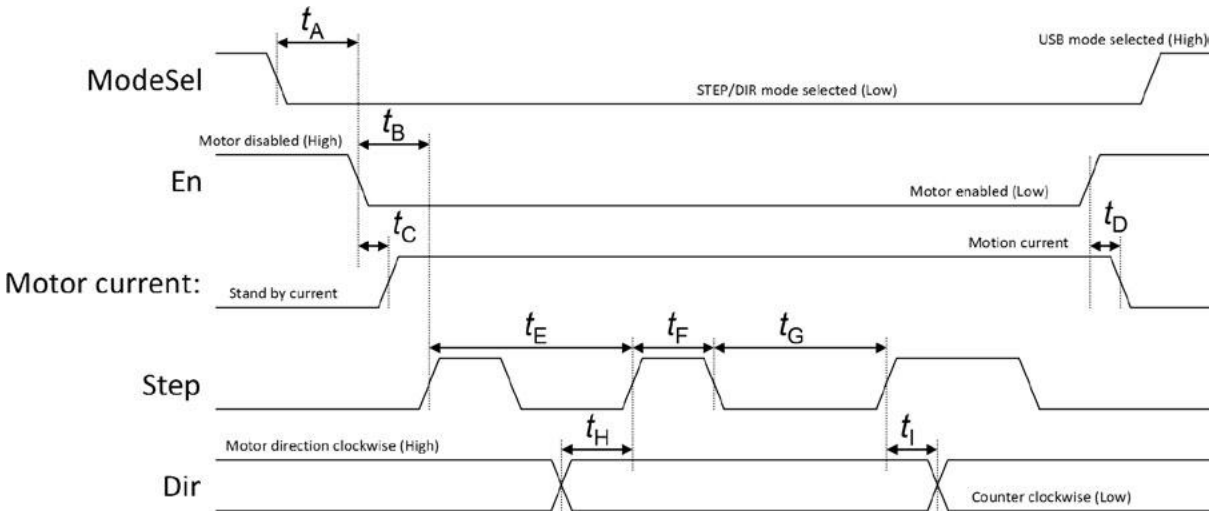


Figure 20. "Step-Dir" mode input signal timing requirements.

Symbol	Description	Min.	Typ.	Max.	Unit
tA	ModeSel wait time. Controller switches to "Step-Dir" mode after ModeSel pin goes low	1			s
tB	Wait time for first valid STEP pulse after "En" pin goes low	20			ms
tC	Time constant then motor current reaches motion current value after "En" pin goes low	15	18	20	ms
tD	Time constant then motor current reaches stand by current value after "En" pin goes high	15	18	20	ms
tE	STEP pulse period	35			μs
tF	STEP high-level time	5			μs
tG	STEP low-level time	10			μs
tH	DIR setup time	5			μs
tI	DIR hold time	7			μs

- 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 20 (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 20 (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

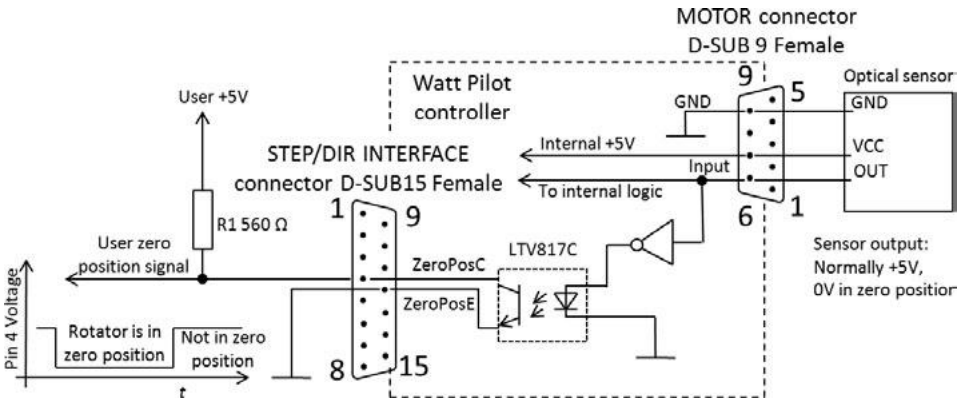


Figure 21. Zero position input circuit diagram for controllers with serial numbers starting with “6ATT”.

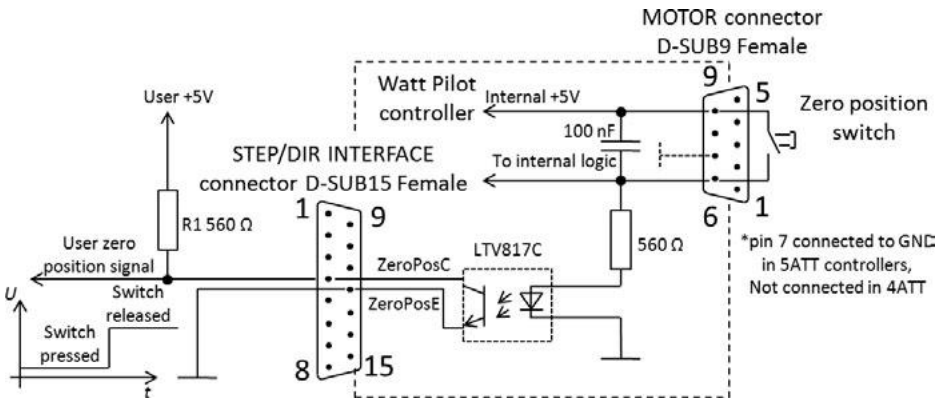


Figure 22. Zero position input circuit diagram for controllers with serial numbers starting with “4ATT” and “5ATT”.

Warning!

“6ATT” controllers support every Watt Pilot 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 “Watt Pilot 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 “Watt Pilot controller connection examples and input circuit diagram” on page 26).

Attention!

“Watt Pilot” 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.

5.7. “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.

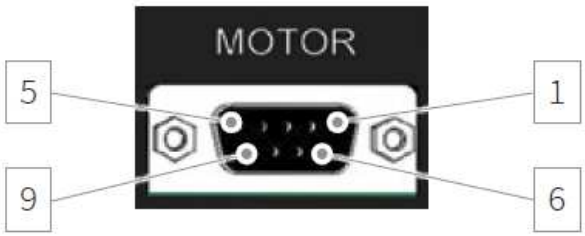


Figure 23. Controller “MOTOR” connector.

Table 4. “MOTOR” connector pin out

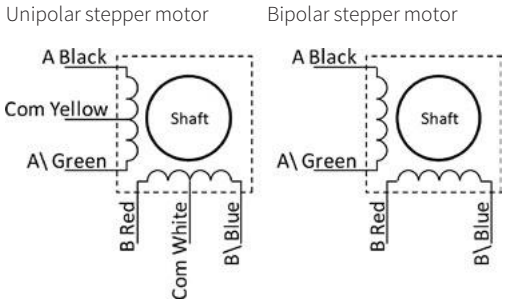
Pin No.	Controller serial number begins with:		
	“4ATT”, see Figure 22 on page 23	**“5ATT”**, see Figure 22 on page 23	**“6ATT”**, see Figure 21 on page 23
1	Motor winding B output (usually red wire)		
2	Motor winding B\ output (usually blue wire)		
3	Motor winding A\ output (usually green wire)		
4	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 Watt Pilots 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 21 on page 23 and Figure 22 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.

5.8. 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 24. 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 mm^2, or ≤20 AWG) to minimize wiring impact to motor noise.

5.9. Watt Pilot controller connection examples and input circuit diagram

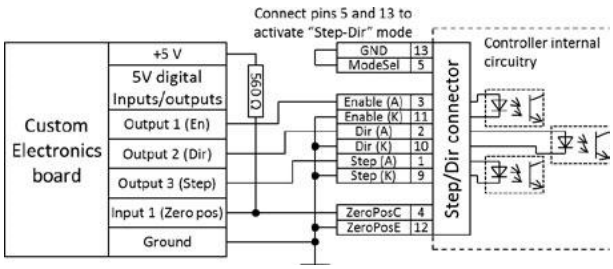


Figure 25. Connecting external equipment to use Watt Pilot controller in "Step-Dir" mode.

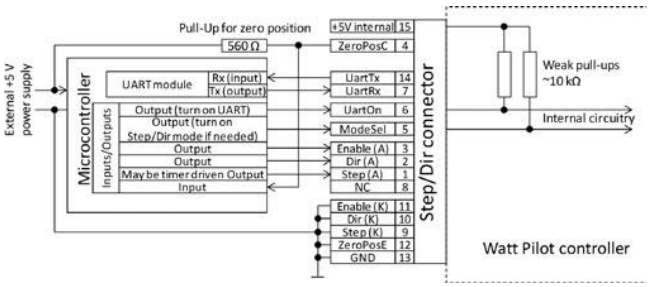


Figure 26. Connecting Watt Pilot controller to microcontroller employing all of Watt pilot features

6. Writing Software for Watt Pilot

6.1. List of supported operating systems for USB drivers

In order to communicate with Watt Pilot, USB drivers are necessary. These are available for more operating systems than "Watt Pilot" 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. Watt Pilot 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".

6.2. 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

6.3. Identifying serial port name

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

In case only drivers were installed (no "Watt Pilot" 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.

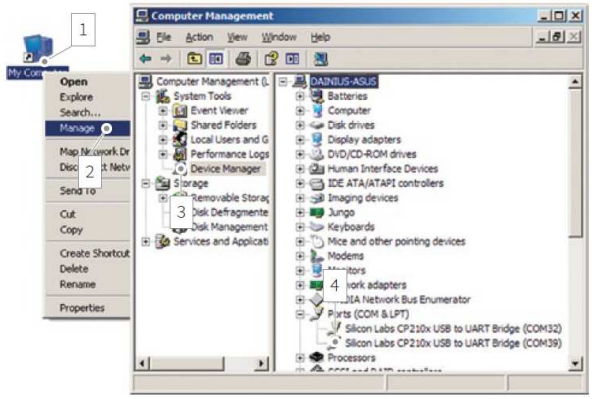


Figure 27. Finding Watt Pilot serial port name using Windows "Computer Manager".

Third way to identify Watt Pilot 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 Watt Pilot port by executing command "root | dmesg | grep cp210x":

```
root@Aivaras:/home/Aivaras# installpkg Downloads/cutecom-0.22.0-i486-1as.txz
Verifying package cutecom-0.22.0-i486-1as.txz.
Installing package cutecom-0.22.0-i486-1as.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-i486-1as.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 driver
[ 1196.500459] cp210x ttyUSB0: cp210x converter now disconnected from ttyUSB0
[ 1196.500493] cp210x 5-1:1.0: device disconnected
[ 1202.112687] cp210x 5-1:1.0: cp210x converter detected
[ 1202.349780] usb 5-1: cp210x converter now attached to ttyUSB0
root@Aivaras:/home/Aivaras#
```

Figure 28. Finding Watt Pilot serial port under Linux. Screenshot is taken on Slackware Linux 13.37 32 bit OS.

In the picture above we can see that one Watt Pilot (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.

6.4. Serial commands and protocol

Watt Pilot is a slave device and computer is a master device. That means that PC sends data requests to attenuator, and attenuator must respond. Watt Pilot 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.

Watt Pilot controller writes all received bytes to internal buffer. If it receives "carriage return" symbol (or '\r' in C++ denotation, 13'th 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.

Watt Pilot 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 erminal 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 20). 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 20). 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 watt pilot.

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.

r x 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. Watt Pilot 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 μs

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 Watt Pilot 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 20). 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 20). 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 15). 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 15). 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;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

6.5. Software recommendations

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 28 on page 27.

For Windows OS it is recommended to use free tool “terminal.exe” from https://sites.google.com/site/terminalbpp Figure 29 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. Watt Pilot 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.

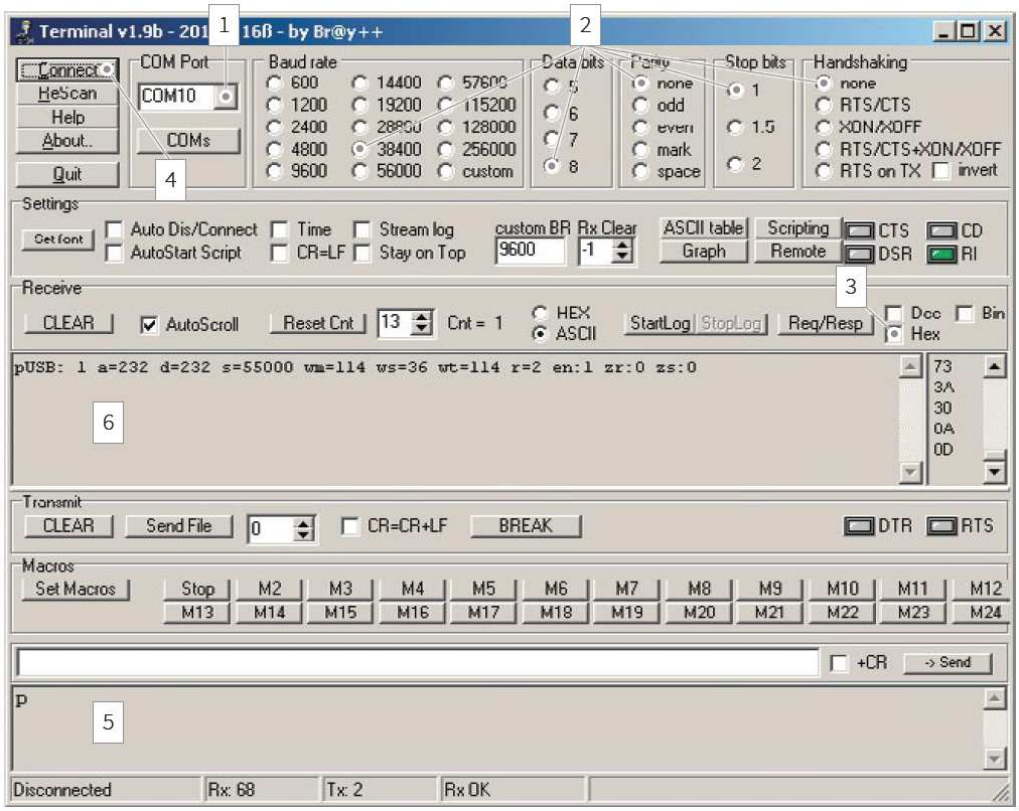


Figure 29. “terminal.exe” window with “p” command sent.

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

Figure 30. 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.

6.6. 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.

6.7. 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 ϕcan be calculated from "*ratio*": $\varphi = \cos^{-1}(\sqrt{ratio})$ (degrees). In order to get motor step position "*steps*" from waveplate rotator angle φ, use relation $steps = \varphi \cdot k \cdot r$, 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 "Watt Pilot" 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:

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

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 "Watt Pilot" 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.
publicInt32 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.
publicInt32 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.
publicdouble 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.

7. Troubleshooting

8.1. Real laser power does not match shown in software

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

8.2. “Upgrade controller firmware now?” message appears

Sometimes Watt Pilot software will show dialog, asking whether to update firmware:

Figure 36. 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.

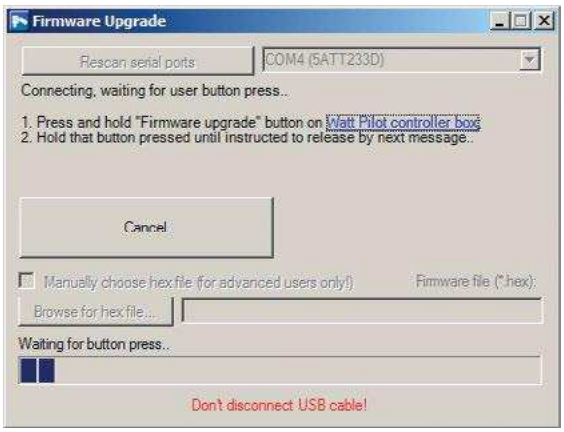
Warning!

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 36. “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.

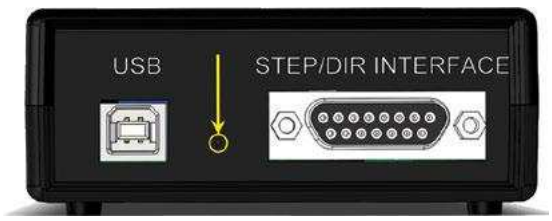
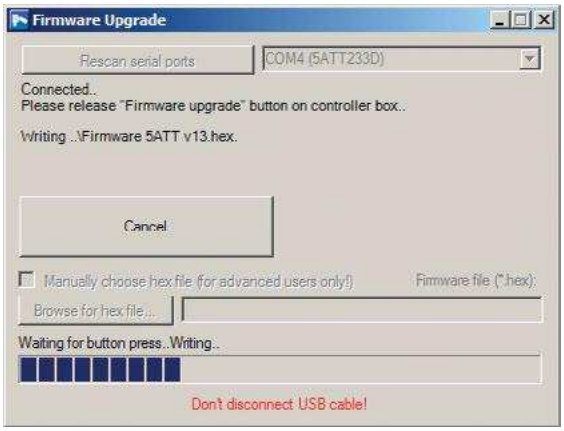


Figure 37. “Firmware upgrade” button location inside Watt Pilot controller.

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 “Watt Pilot control” window will start.

8.3. 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 Watt Pilot.

Figure 38. Error, thrown if device firmware becomes corrupted.

In order to recover, follow these steps:

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

3. Press and hold down “Firmware upgrade” button located inside controller box, see Figure 37 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 “Watt Pilot” software and try to use the device;
7. Firmware will be correctly rewritten automatically. Device will be ready to use after one minute.

8. List of Tables

Tel. +370 527 25 738

Fax +370 527 23 707

sales@altechna.com

Mokslininkų st. 6A

Vilnius, Lithuania

www.altechna.com