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Innovative resource efficient technologies, processes and services

ZEPHYR project – Deliverable D5.2

User's Manual

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Table of Contents

List of abbreviations:

- DB = data base
- HVAC = Heating, Ventilation and Air-Conditioning

1. Executive summary

This deliverable define the user's Manual of the growth chamber beside its installation, calibration, maintenance and troubleshooting.

The deliverable is structured with the following sections:

- Installation of the system
- Operation
- Calibration
- Preventive maintenance
- Specifications
- Electrical schematics
- Troubleshooting
- Spare parts replacements
-

Reference documents

This work has been carried out taking as reference the following documents:

- ✓ ZR-Cometart-WP2_D4.1 _Final-Mechanical-Design
- ✓ ZR-Valoya-WP2_D4.2 _Final-NewLEDLamp-Design
- ✓ ZR-IFAM-WP2_D4.3 _Final-NewSensors-Design
- ✓ ZR-ADV-WP2_D4.4 _Control-System
- ✓ ZR-ROBO-WP2_D4.5 _Robotic-Device
- ✓ ZR-Exergy-WP2_D4.6 _Power-System
- ✓ ZR-ROBO-WP4_D4.7 _Complete system integrated

2. Section 1 – Equipment Overview

1	20 feet container
2	Solar panel
3	External power supply
4	Power system
5	Batteries pack
6	Control system
7	HVAC system
8	Growth chamber

Figure 1: Zephyr system Overview

3. Section 2 – Specification

Futures	**Specification**
Size	5898 x 2350 x 2390 mm
Total weight	7 tons
Growth chamber capacity	10 shelves, 2 tries each, 144 pots each
Growth chamber volume	6,36m3
Power needed	1900 watts max load with a daily average of 1450 watts
Autonomy under batteries power	One day

4. Section 3 – Installation

4.1 Choosing a Location

To ensure proper operation, the unit must be located on an outside firm level surface, capable of supporting approximately (machine weight: 600kg. The entire system, including container, batteries, HVAC, etc is

about 7 tons). The unit should be placed in a free space and positioned in order to have solar panels oriented to south for better exposition to the sun light.

The unit requires:

- Optionally a dedicated electrical connection. Power requirements is 1900 watts max load with a daily average of 1450 watts (300wattsonly rotating, translation and watering systems). The unit must be always connected to the ground
- Water connection: Manual filling of the 200 litters tank
- Water evacuation: Use the same pump for the filling of the irrigation tank deflecting the two valves (faucets) manually

4.2 Unpacking after transport

Place the container on a flat or levelled floor, with the PV side (window side) oriented to South

First operation: ground connection; do not do anything before the ground connection is established and tested by an electrician.

Connect the command of the PV panels hydraulic mover and place the PV panels in the right positions, according to the following picture; a movie of the operation is available at: https://www.youtube.com/watch?v=1zdJh4jpHjQ
Block the lower row of PV panels with the opposite bars

Figure 2: PV panels installation

Remove the steel bars blocking the shelves and check the system components against the drawings in this manual;
check the shelves are free to tilt on their longitudinal axis; be sure the transmission chain is free from any obstacle. store the bars outside the conditioned area

4.3 Packing before transport

Remove the bars blocking the lower row of PV panels, then connect the hydraulic command and move the roof until horizontal position. Put the lower panels inside the roof (please refer to the video mentioned above

4.4 Transportation

4.4.1 Handling

The zephyr container has a weight of 7 tons and should be handled by an adequate mover, like in the following picture (Milan, 2015)

Figure 3: Container handling

4.4.2 Precaution to consider during transport

The mover should place the container on an truck able to transport standard TEU containers, like in the following picture and adequately blocked before starting the transport

Figure 4: Container transportation

5. Section 4 – Operation

5.1 Description of the user's interface

A user interface is that portion of an interactive computer system that communicates with the user. Design of the user interface includes any aspect of the system that is visible to the user. The user interface is becoming a larger and larger portion of the software in a computer system. Design of a user interface begins with task analysis; an understanding of the user's underlying tasks and the problem domain. The user interface should be designed in terms of the user's terminology and conception of his job. A good understanding of the cognitive and behavioural characteristics of the particular user is thus important. Good user interface design works from the user's capabilities and limitations. Knowledge of the nature of the user's work and environment is also critical.

Zephyr system User Interface has been designed and developed to allow a user, in this particular case a biologist or a technician to decide the values of a set of predefined parameters (system inputs) that will drive the behaviour of the growth chamber, lighting irrigation, image capturing, etc.., to access the information collected by the system, sensor readings, status signals, notifications... considered as system outputs.

The system is intended to be operated using a graphical user Interface (GUI), as front end of a standalone software application running locally in a computer. The user interface main functions are to interact with the configuration module, to manage and set the subsystems individually -or grouped- (ie: lighting, watering, motion, …), manually or defining automated routines, to monitor the parameters reported back by the subsystems and the wireless devices fitted with specific sensors.

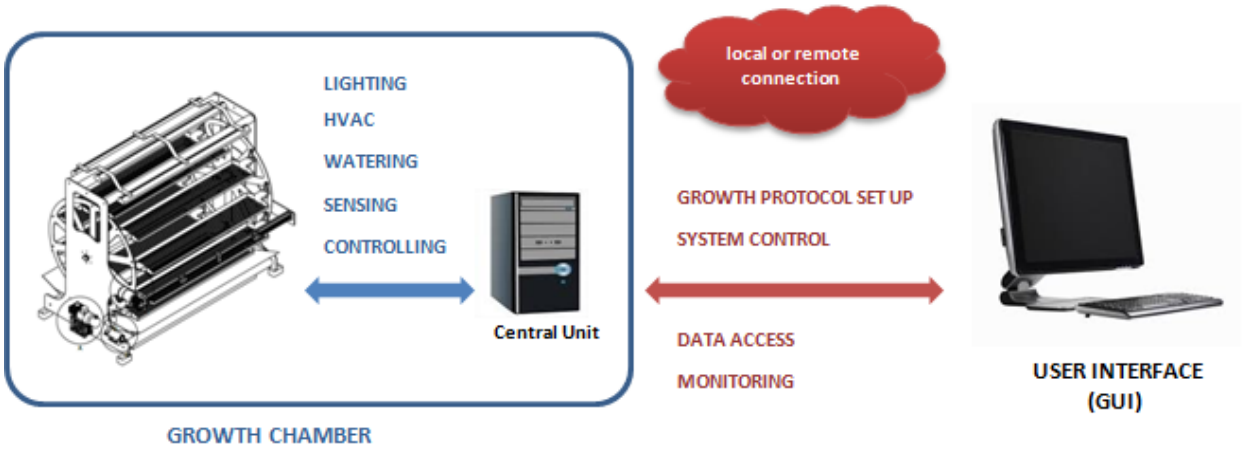


Figure 5: Zephyr system UI

5.1.1 Zephyr Scheduler installation

The software developed and the libraries needed to integrate all the subsystem functionality is contained in an application file of less than 7MB. The installation is very straightforward, this application file can be copied to any location in a computer and the application can be launched using the **Zephyr Scheduler.exe** file-type

Figure 3 describes the content of the application file and the different libraries developed and integrated.

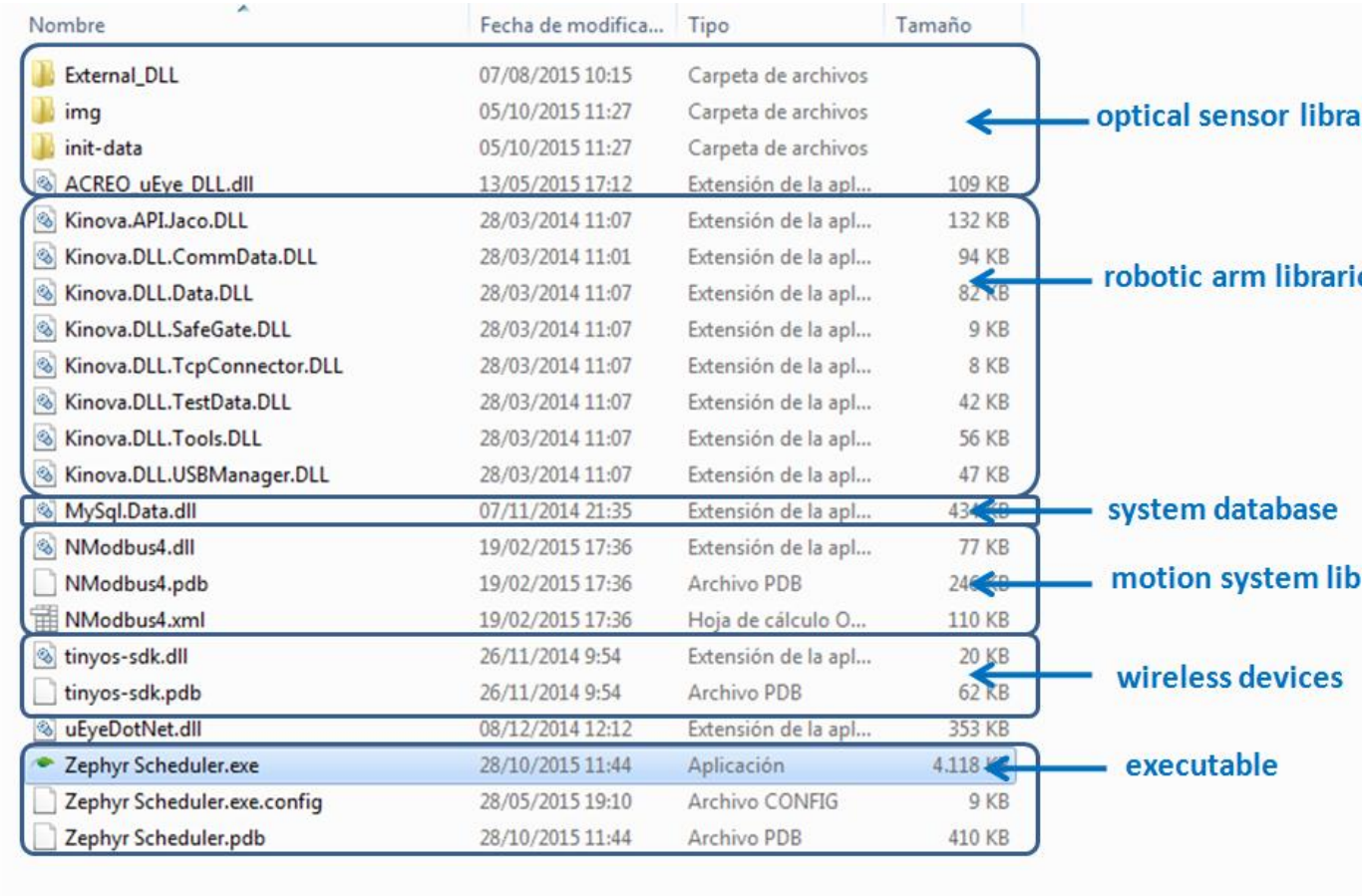


Figure 6: Zephyr application file content

The **"img"** folder is the location where all the images captured by the system are stored along with the processed information generated by the greenness calculation algorithm. The folder is organised in successive folders corresponding to the tray- and pot number where the image originated. The image files are labelled with the date, time, and camera ID.

The **"Init-data"** folder is where all the HSV configuration files are stored; it can contain a number of these user-defined configuration files. Any of these files can be selected during operation when defining the processing parameters.

5.1.2 Configuration Tab

After launching the Zephyr scheduler application, the user can access the configuration tab (Figure 7) and set up the connection parameters to enable the communication with the subsystems through different physical interfaces (LAN, Serial COMs,..) and initialize the system Database (DB) using the connect buttons.

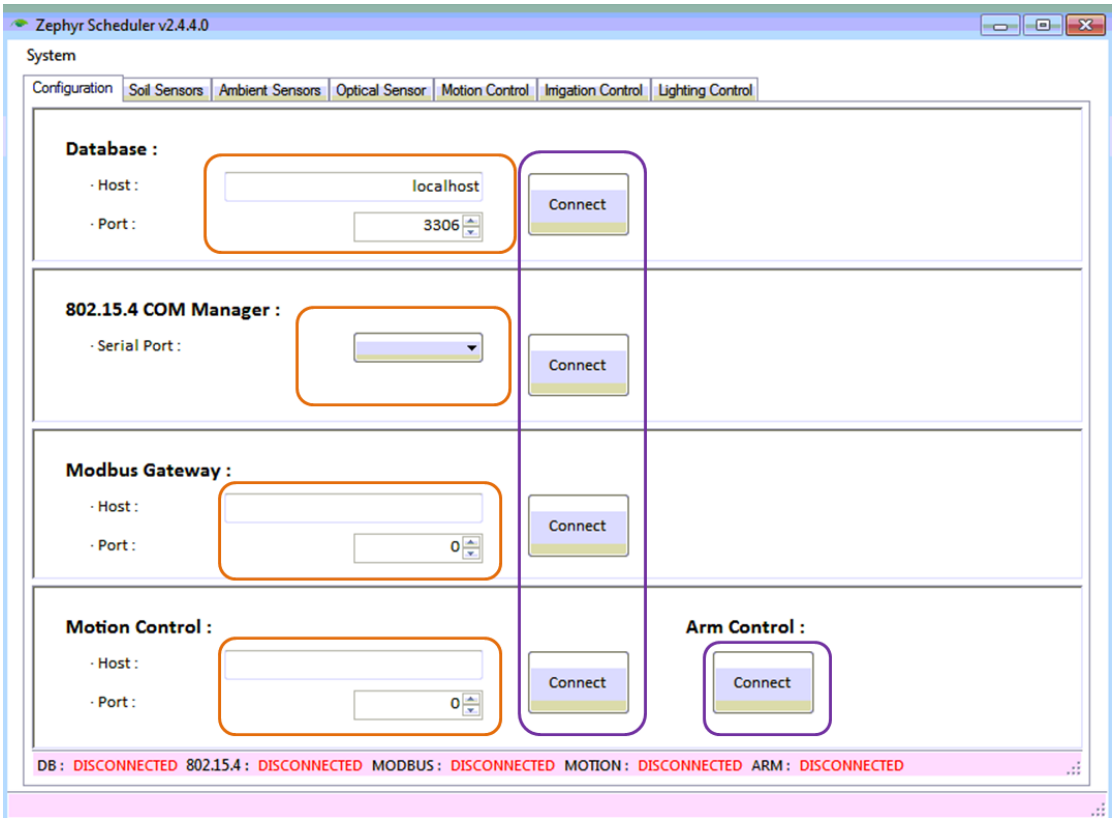


Figure 7: ***Configuration tab***

The subsystem connection status is updated and displayed at the bottom of the screen (Figure 8).

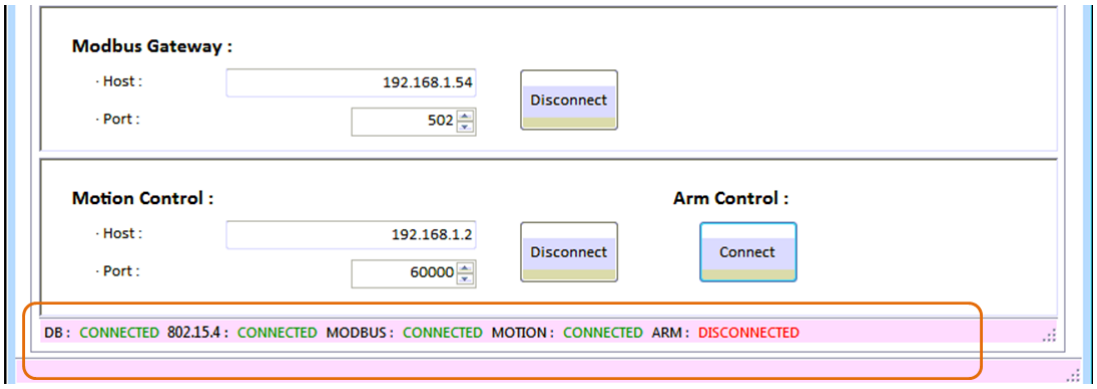


Figure 8: ***subsystems configuration and connection***

A proper initialization requires the all the subsystems communication interface (DB, 802.15.4, MODBUS, MOTION, ARM) to be in a **CONNECTED** status (Figure 9).

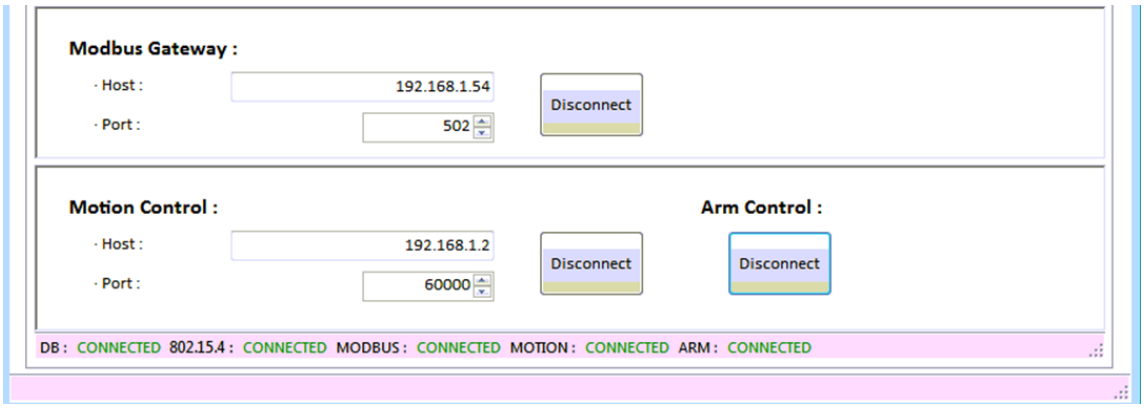


Figure 9: ***all subsystems connected - ready to work***

5.1.3 Soil sensor Tab

The soil sensor tab allows selection of a specific wireless sensor ID no. (11 to 20) and a specific parameter (water content, temperature, soil conductivity) from a predefined dropdown menu (Figure 10). The last reading available for the selected parameter is displayed on the screen with the correspondent time stamp.

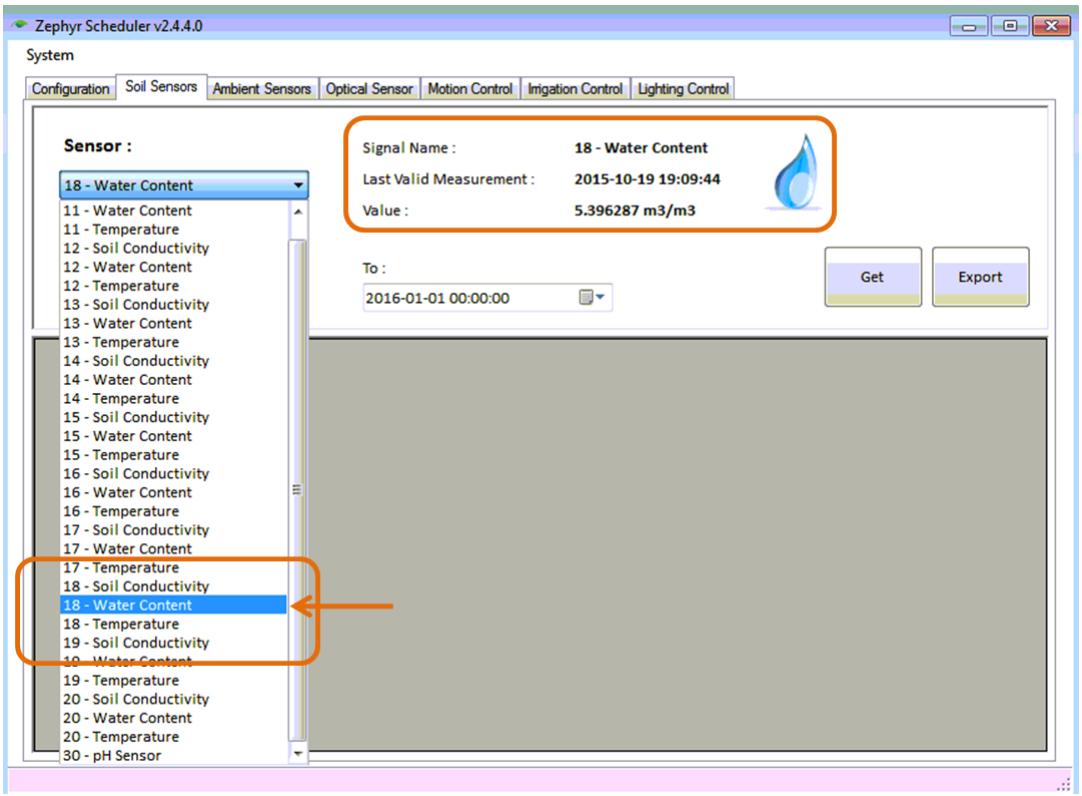


Figure 10: ***soil sensor selection and last reading display***

Other functionalities in this tab allow also to define a time interval (start/end date) and retrieve all the data stored in the system DB for that time interval clicking on the "**Get"** button. The data available will be displayed as a list and can be exported in CSV format using the "**Export"** button (Figure 11 and Figure 12).

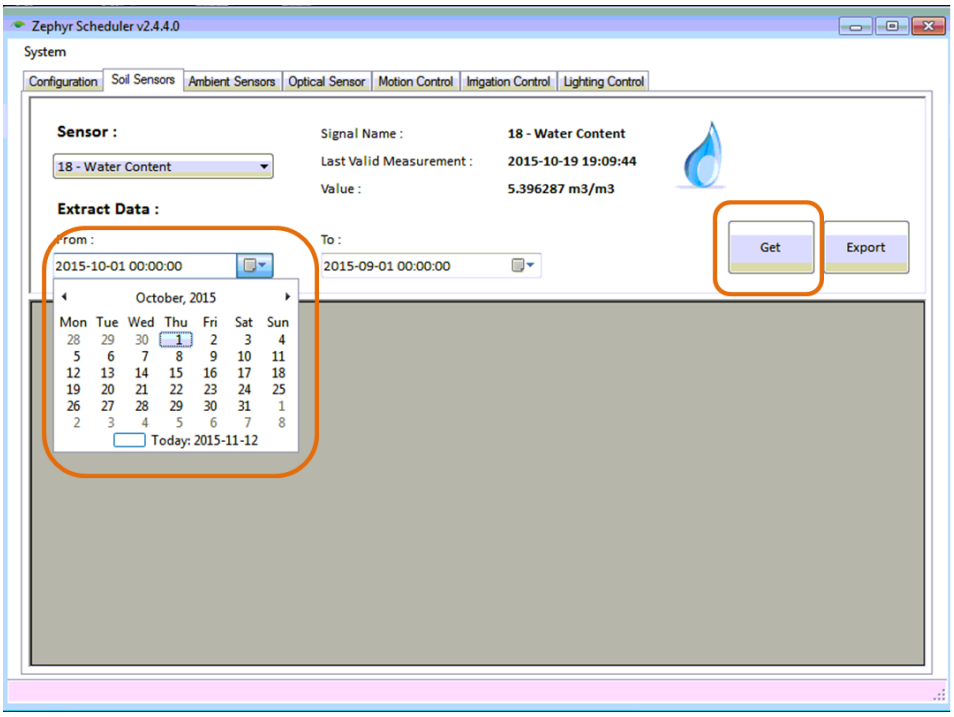


Figure 11: ***soil sensor data display - time interval definition***

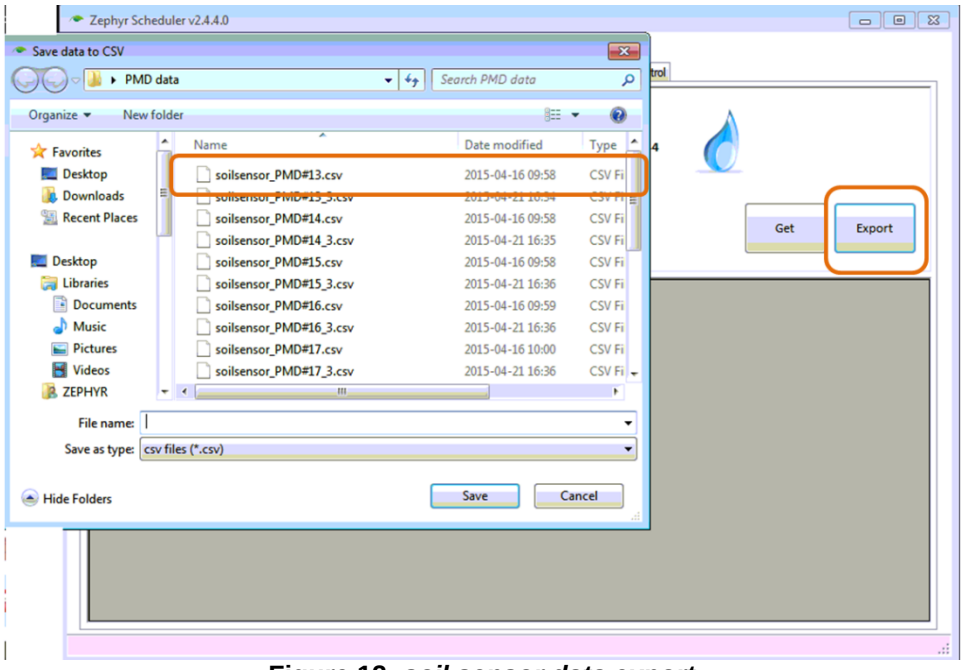


Figure 12: ***soil sensor data export***

5.1.4 Ambient sensor Tab

The Ambient sensor tab has similar functionalities than the soil sensor tab, but in this particular case the ambient sensors provide readings of temperature, humidity and CO2 level from 2 wireless sensors, one located inside the growth chamber (controlled environment) and the other outside the growth chamber close to the operator (non-controlled environment)

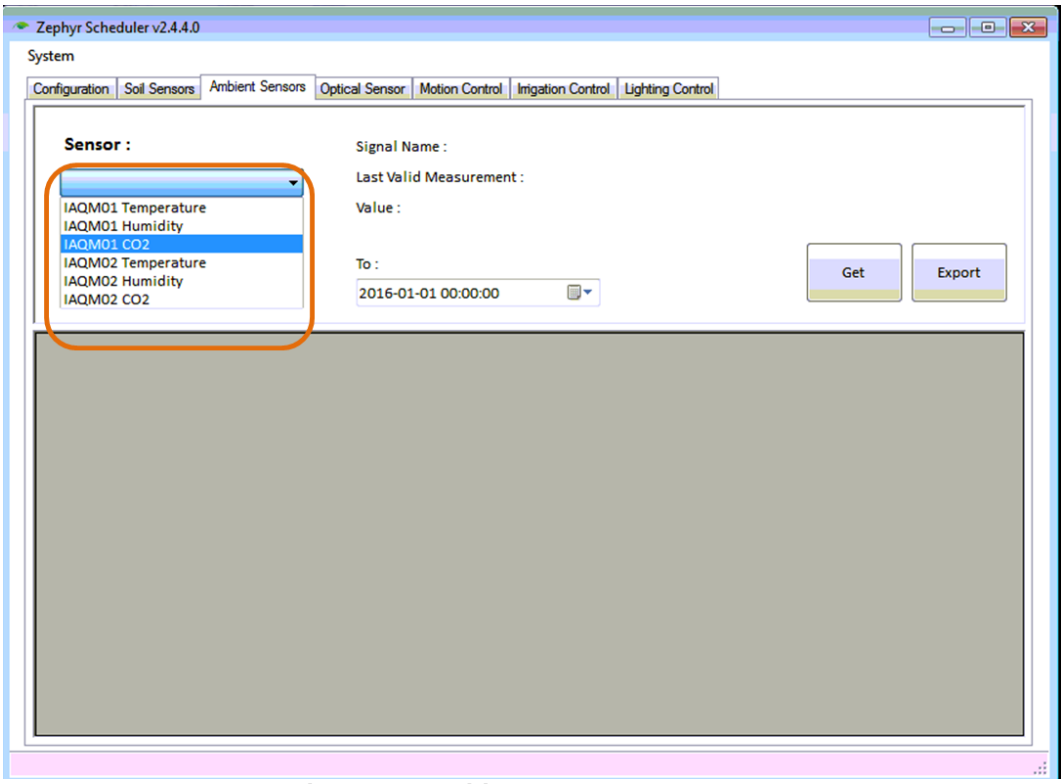


Figure 13: ***ambient sensor parameters***

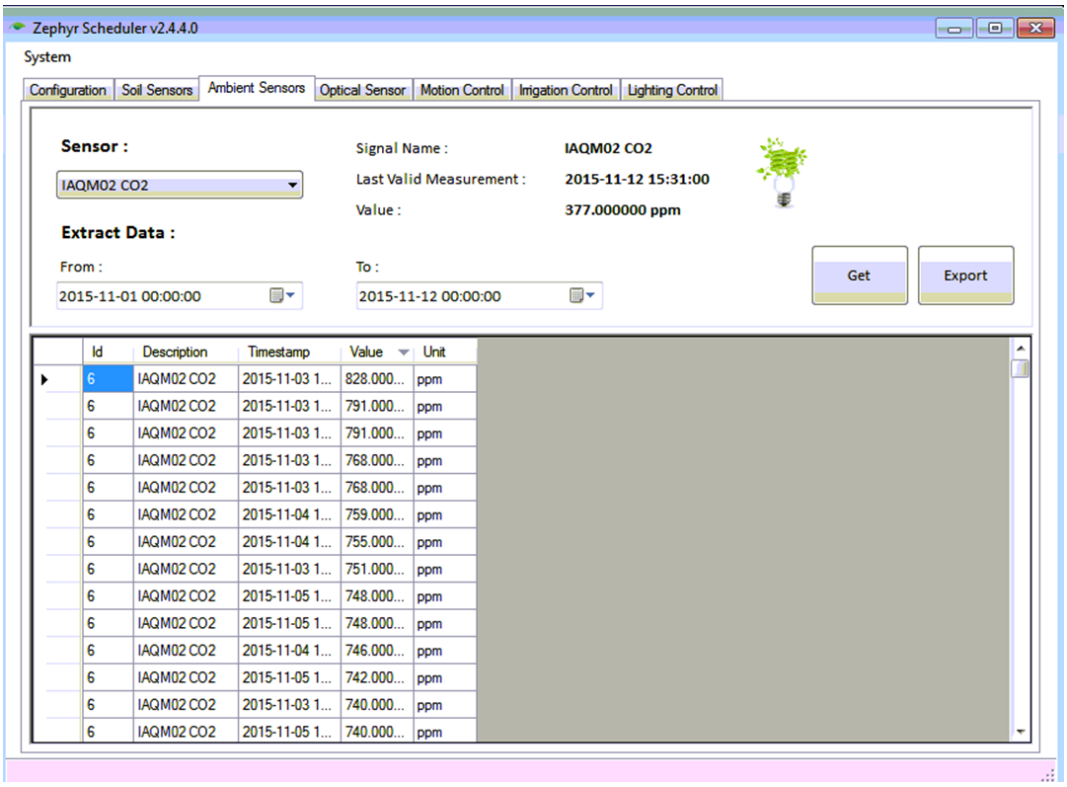


Figure 14: ***ambient sensor data display***

5.1.5 Optical sensor Tab

The optical sensor tab allows for capturing and processing of images from 2 cameras integrated within the robotic arm. The image capturing requires coordination with the motion system, i.e. the robotic arm must point the cameras to a specific tray and pot (image position) and the motion system must ensure the selected tray is stopped at that specific image position. Assuming the robotic arm and the selected tray are properly positioned, image capturing and processing (greenness calculation) is done by clicking on the "**Start Analysis"** button (**Errore. L'origine riferimento non è stata trovata.**). The greenness calculation is done considering the HSV **configuration file** selected. This file must be previously stored in the "init-data" folder in order to be accessible (Figure 15 and Figure 16).

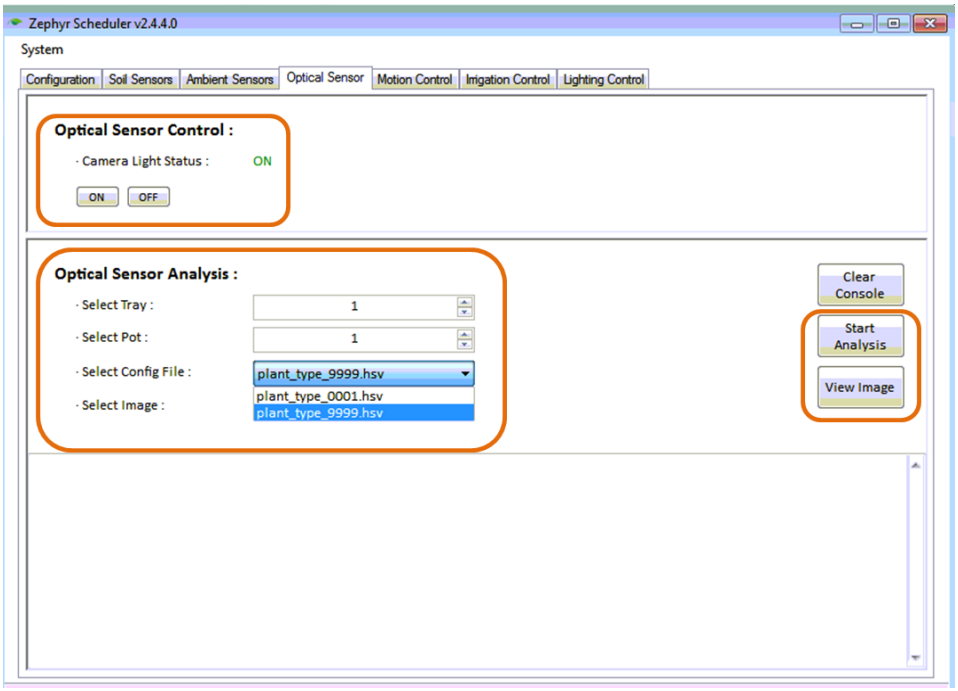


Figure 15: ***Image capturing settings***

There is a LED lamp integrated with the camera support to guarantee repeatable lighting conditions when taking the pictures. This LED lamp (camera light) can be switched ON-OFF using the optical sensor Control buttons and the light status is always displayed.

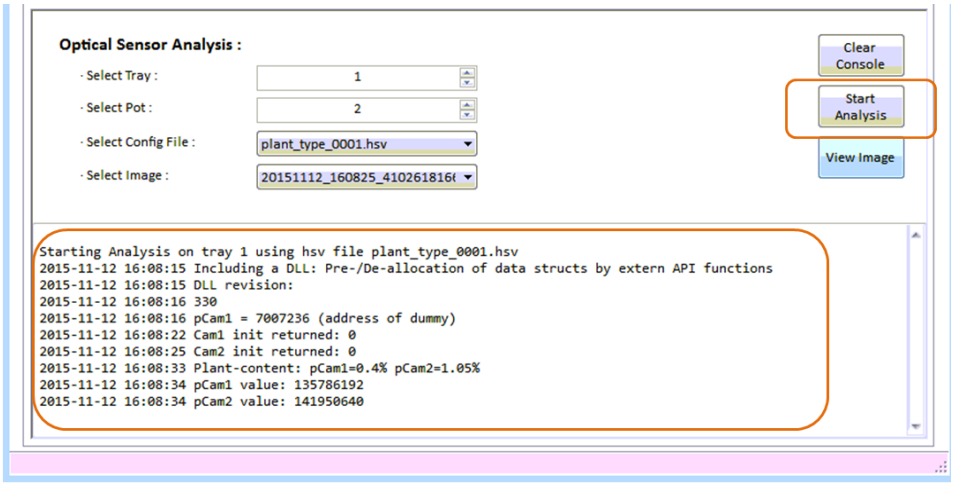


Figure 16: ***Image HSV analysis (Greenness)***

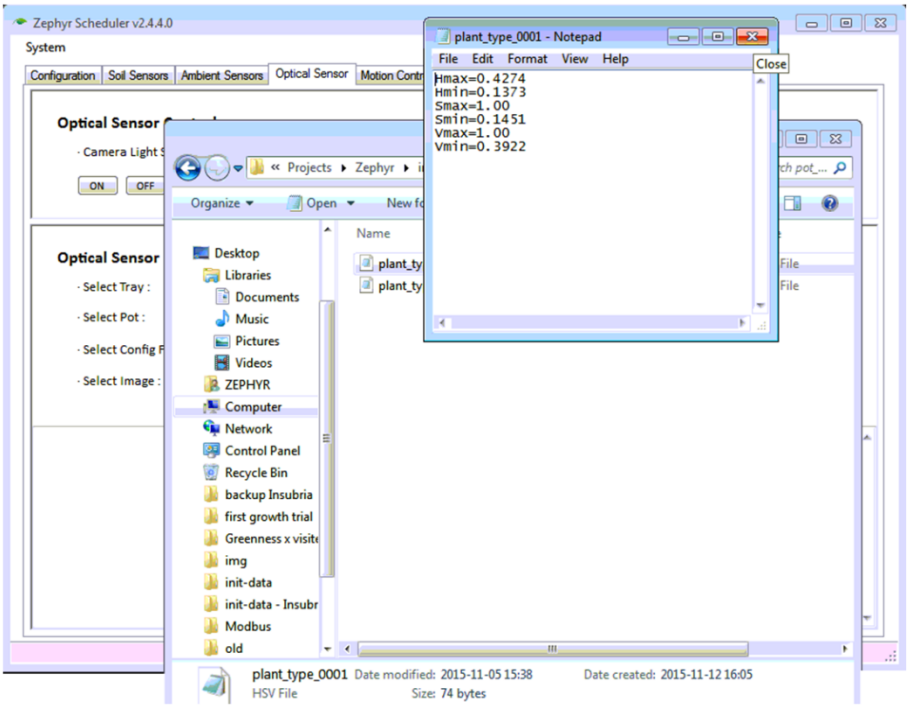


Figure 17: ***Image HSV configuration file***

The **"View Image"** button allows to load and display the images captured/stored from a specific tray/pot (Figure 18).

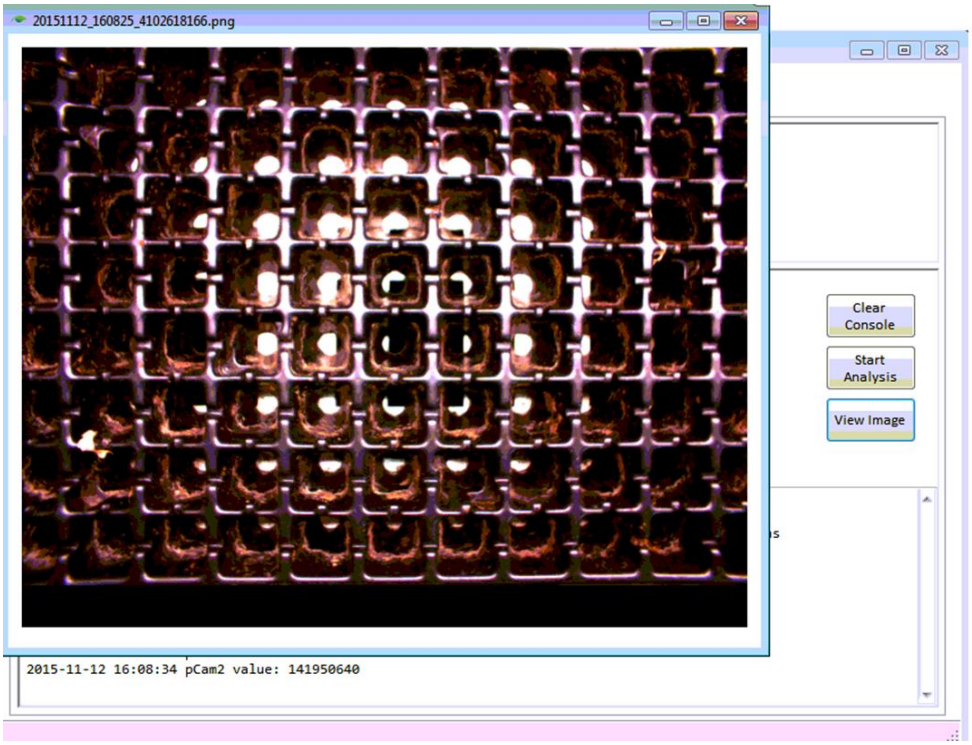


Figure 18: ***View Image***

5.1.6 Motion control Tab

The motion control tab allow the user to manage 2 motion systems, the robotic arm positioning and the tray rotation system. The robotic arm can be positioned at 3 predefined positions: PICTURE, INTRERMEDIATE, HOME and sent to any position manually introducing X,Y,Z and Theta coordinates in CUSTOM mode.

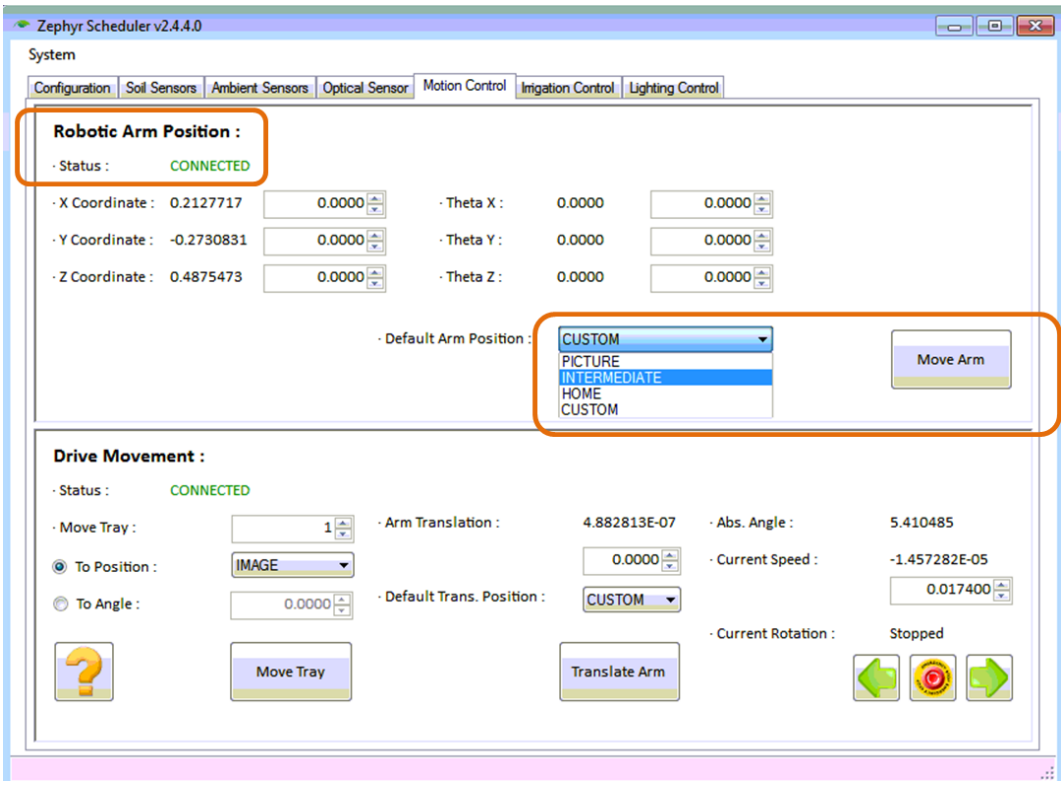


Figure 19: ***Motion control – Robotic arm***

Drive movement menu is used to set the rotation speed and the rotation direction (anti/clockwise) and to send any tray (1 to 10) to a predefined position (IMAGE, IRRIGATION) or to a specific location using the angle positioning option. This menu display continuously the positioning values (abs. angle) and system status (stopped, clockwise, anticlockwise)

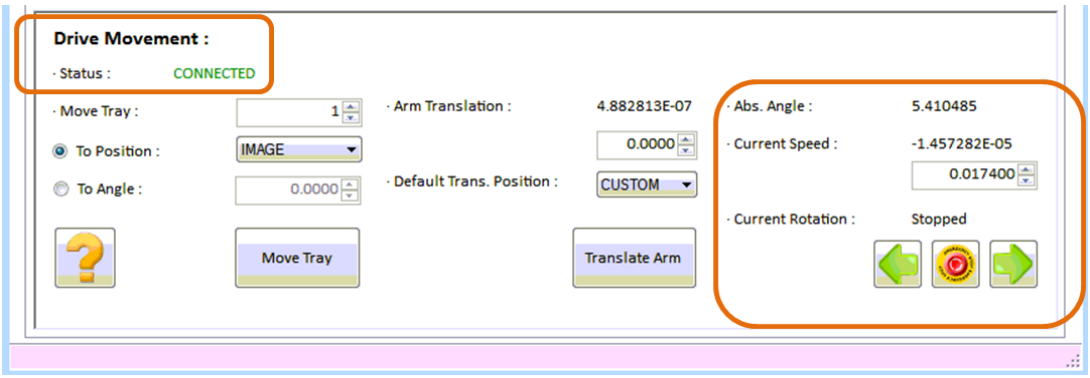


Figure 20: ***Motion control – Rotation system***

5.1.7 Irrigation control Tab

The irrigation control tab provides information on the status of the tub an tank level, the filling pump and the drain valve and supports 2 types of control, manual and automatic. The manual control allows to fill/drain the tub at any time, **Auto fill** option can be used to fill the tub up to a predefined level (pot tray). The automatic mode include options like: time scheduling (date/time), (tray) immersion time, cycle repeatability (hours) or SWC trigger, using water content last reading from a specific soil sensor to decide whether to start the cycle or not.

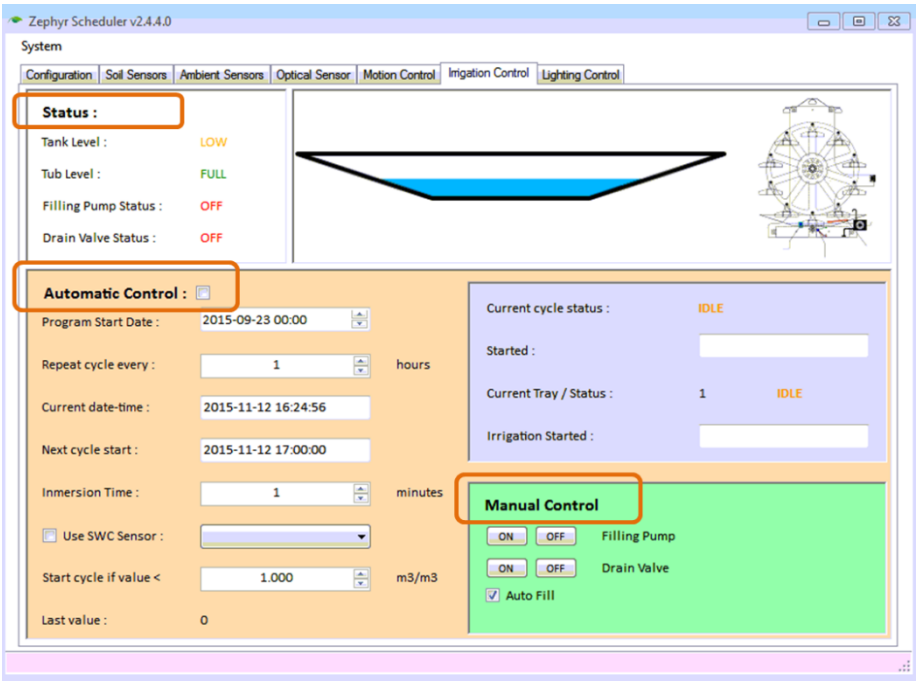


Figure 21: ***Irrigation control***

The irrigation cycle is coordinated with the rotation system (IRRIGATION) and the robotic arm position (HOME) before starting.

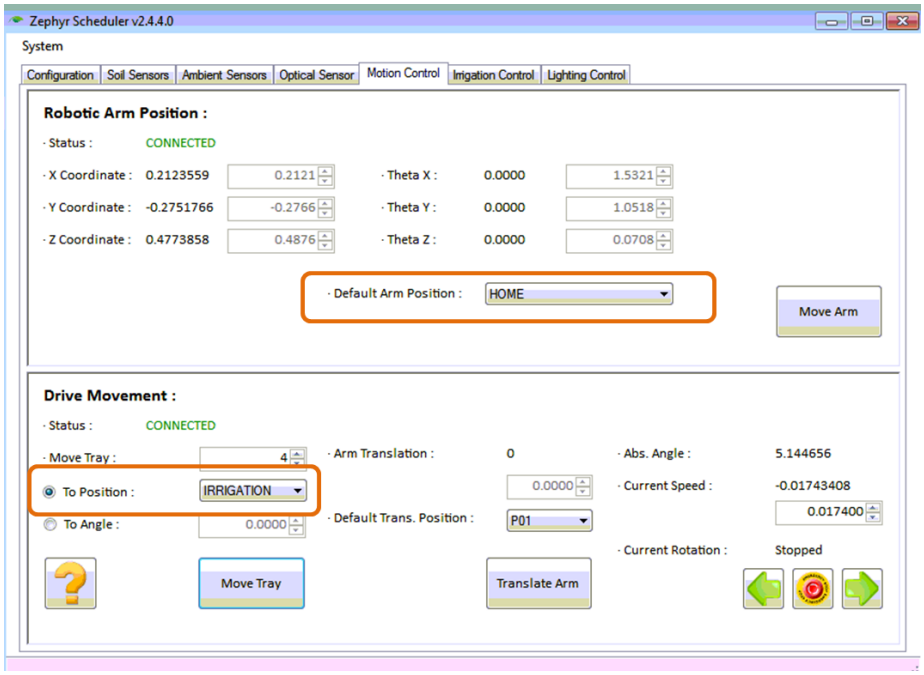


Figure 22: ***Motion control system – irrigation positioning***

5.1.8 Lighting control Tab

The lighting control tab is designed to allow the user to define the LED luminaire status (**ON-OFF**) and the PAR level, **Dimmer level** (0-100%). The PAR level (µmoles/m2.s) is measured by a PAR sensor installed in the growth chamber at the tray distance from the luminaire. An automated mode is also possible for the lighting system, the user can define an combine different time slots (scheduling) with specific configuration for the luminaire status (on/off) and the PAR level (dimmer percentage) to be applied daily.

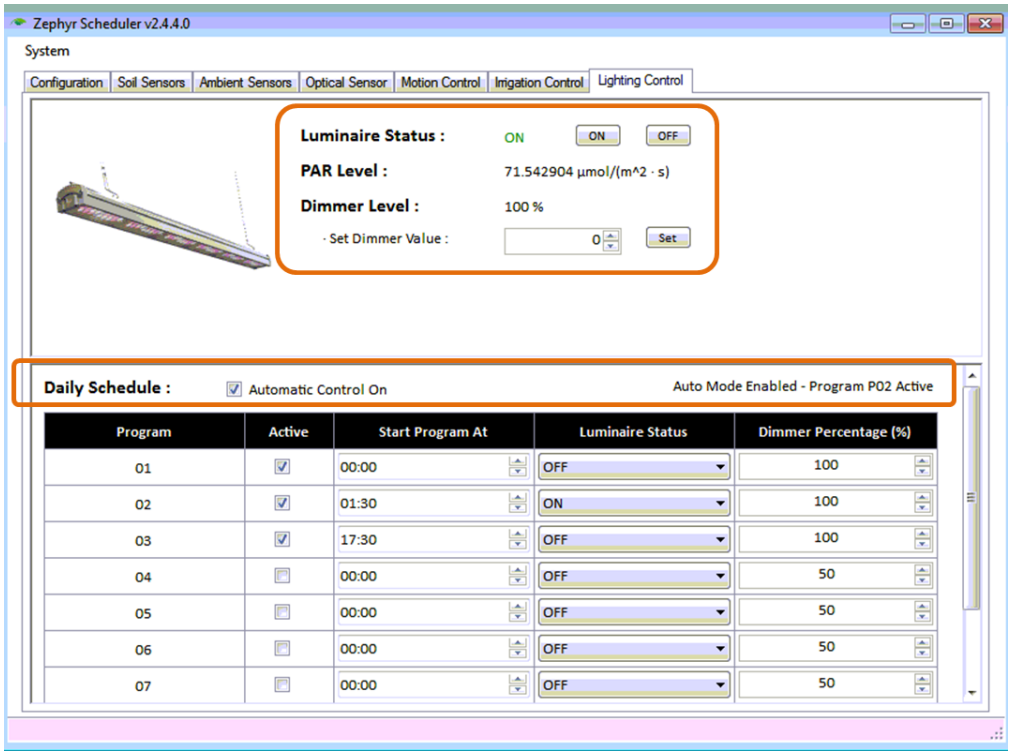


Figure 23: ***Lighting system***

5.1.9 System Data output

The system stores all the data collected periodically from the wireless devices in the database, these data can be accessed at any time from the soil and ambient sensor tab menus and exported in csv format for further analysis.

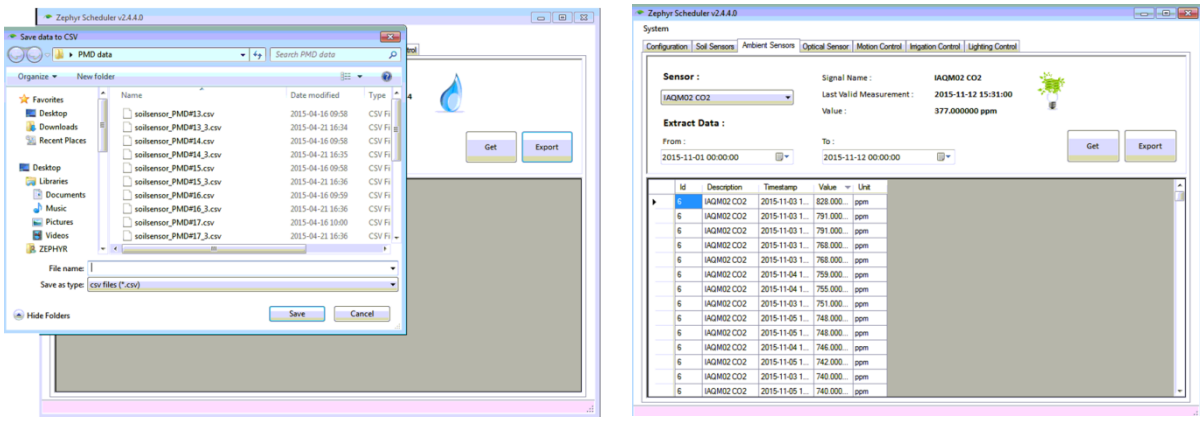


Figure 24: ***wireless devices output data***

The images captures by the optical system (2 cameras), are stored in the image file under the correspondent tray and pot, i.e **\img\tray_08\pot_02.** The **.hsv** config file is stored under **init-data\tray_08\pot_02**; this file can be edited or new ones added (Figure 25).

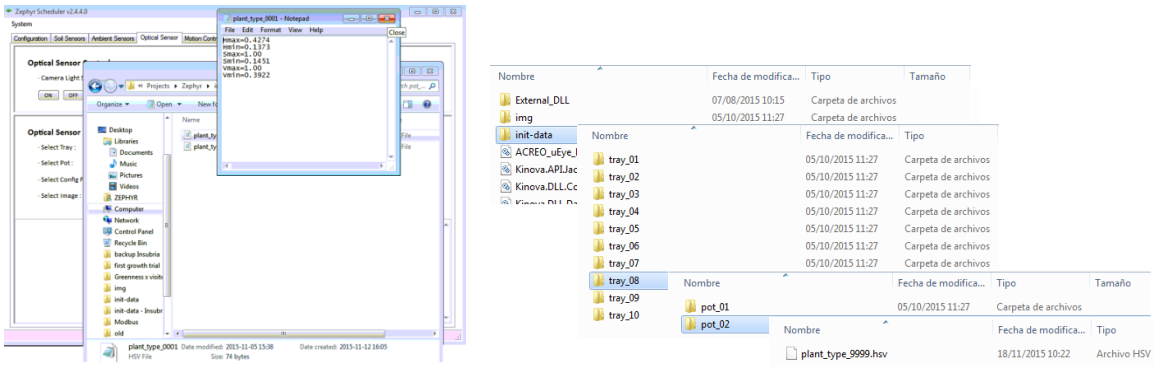


Figure 25: ***optical sensor output data***

The results of the image processing is displayed during the operation and stored in the same folder than the images captured (Figure 26).

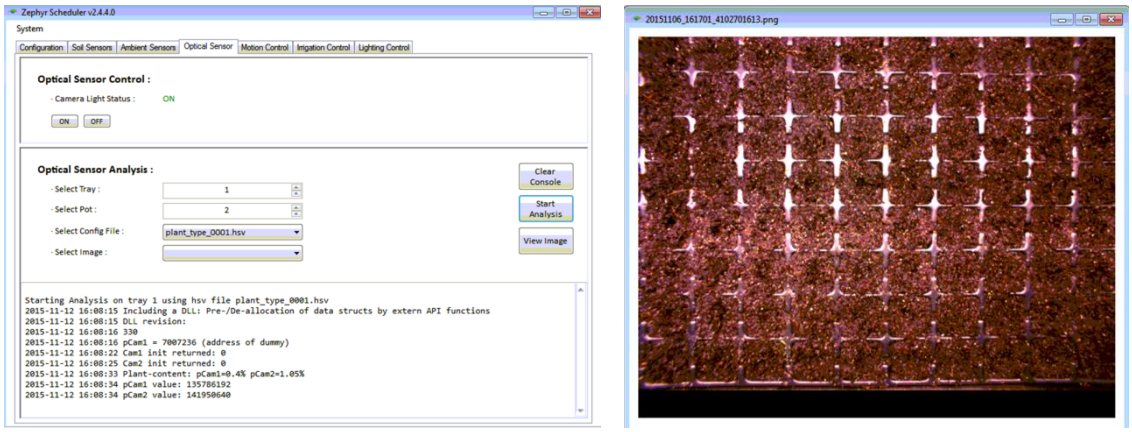


Figure 26: ***optical sensor output data***

6. Section 5 – Calibration

6.1 Calibration of the chamber temperature

The HVAC system is a self-standing system inside the Zephyr Unit: the attached manual of the PLUS 100 THR seasoning controller should be carefully (sections 3,4 and 5) before starting with the operations.

To calibrate the chamber temperature please refer to the section 6.1 in the PLUS 100 THR manual

6.2 Calibration of the chamber humidity

HVAC control panel To calibrate the chamber humidity please refer to the sections from 6.2 to 6.5 in the PLUS 100 THR manual

6.3 Calibration of the soil sensor stick

The soil sensor stick is design to measure between about 30% to 60% volumetric bulk water (m^3/m^3) and soil conductivity between about 0.1 dS/m to 2 dS/m in Jiffy substrate.

The following procedure has been done to obtain a conversion formula between the raw signals from the soil sensor (R, C) and the volumetric bulk water and electrical conductivity of the soil. This procedure is not needed to be done by the User again. However, for critical and/or more accurate measurements, the User can supplemented / modified the water volume calibration procedure with measuring the water content by relative weighing of the soil versus measured PM-D permittivity.

In the PM-D soil sensor system, the resistance R and capacitance C is determined for a specific wet state of the soil. The soil conductivity, σ, and volume water content, θ, is related to R and C according to:

$$R = \frac{A}{\sigma} \quad (1)$$

$$C = \varepsilon_r C_0 \quad (2)$$

$$\sqrt{\varepsilon_r} = b_0 + b_1\theta \quad (3)$$

where A is a calibration parameter, ε_r is the relative permittivity of the soil, C_0 the capacitance between sensor electrodes in air (ε_r =1), and b_0 and b_1 are calibration parameters.

The translation of PM-D resistance readings (R) into soil bulk conductivity (EC_p [S/m]) is done by measuring R in a number of samples of known conductivity, covering an appropriate conductivity interval.

The PM-D sensor stick was calibrated with respect to the conductivity and resistance between the electrodes by using liquid substances with different conductivities (in the same range as for the soil). The conductivity was measured independently with a commercial conductivity meter (CDM210, Radiometer Copenhagen). The result from the conductivity calibration can be seen in Figure 27.

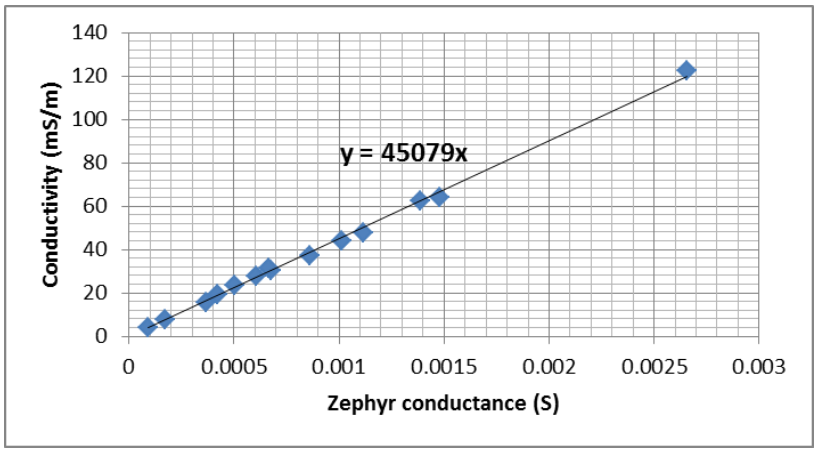


Figure 27. Conductivity versus measured PM-D conductance (1/R).

The sensor stick was also calibrated with respect to the permittivity of the soil and the measured PM-D capacitance between the electrodes, by using substances with different permittivity (Table 1). The result of this calibration can be seen in Figure 28 below.

Table 1. Sample utilized for calibration of capacitance to water content in soil

Sample	Dielectric constant (literature)
PEG (liq)	12.4
Ethanol (liq)	24.3
Methanol	33
Glycerol (liq)	42.5
Tap water (liq)	80

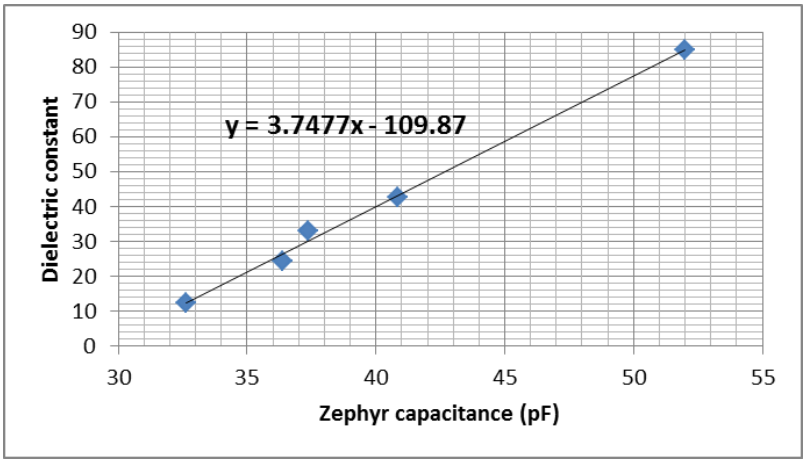


Figure 28. Permittivity (dielectric constant) versus measured PM-D capacitance.

The PM-D readings from measured soil permittivity can be translated into soil volume water content [m^3/m^3]. To do this, the water content measured with the commercial WET-2 soil sensor (Delta-T Devices) was plotted versus the permittivity and the calibration constants b_0 and b_1 (see eq. 2, 3) were determined. The result of this calibration can be seen in Figure 29.

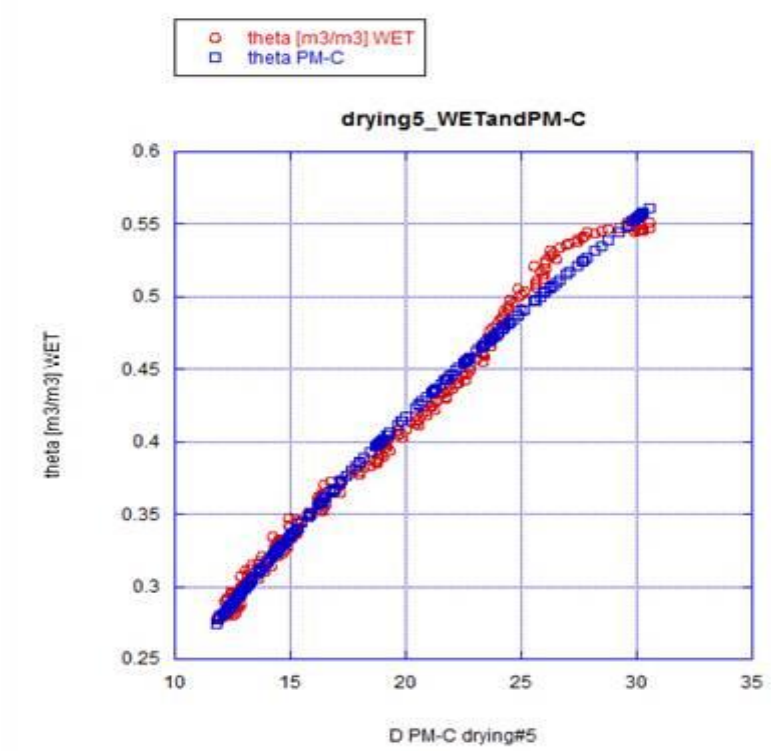


Figure 29. Volume water content (measured with the WET-2 sensor) as a function of permittivity measured with the PM-C sensor stick.

The temperature sensor situated on the microprocessor has been also calibrated by measuring at a constant temperature and correcting the values in the calibration equation.

The conversion equations for the sensors are listed below:

Conversion formulas for the temperature readout (A-value)
#11 ECp [ms/m] = (64.5*(0.631/(9.104395e-6*A+0.0079175))-150.3)
#12 ECp [ms/m] = (64.5*(1.419/(9.104395 e-6*A+0.0079175))-150.3)
#13 ECp [ms/m] = (64.5*(0.595/(9.104395 e-6*A+0.0079175))-150.3)
#16 ECp [ms/m] = (64.5*(0.618/(9.104395 e-6*A+0.0079175))-150.3)
#18 ECp [ms/m] = (64.5*(0.579/(9.104395 e-6*A+0.0079175))-150.3)
#20 ECp [ms/m] = (64.5*(0.647/(9.104395 e-6*A+0.0079175))-150.3)

Conversion formulas for the temperature readout (B-value)
#11 Theta [m3/m3] = ((176.14*(0.463/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603
#12 Theta [m3/m3] = ((176.14*(0.475/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603
#13 Theta [m3/m3] = ((176.14*(0.430/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603
#16 Theta [m3/m3] = ((176.14*(0.431/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603
#18 Theta [m3/m3] = ((176.14*(0.435/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603
#20 Theta [m3/m3] = ((176.14*(0.490/(0.8085-(0.5954-1.4103*9.104395*B)^(0.5))-1)-109.87)^(0.5)-1.3)/7.603

Conversion formulas for the temperature readout (C-value)
#11 T [°C]=((600/1.32)*((C -32768)/32768))-264.94

#12 T [°C]=((600/1.32)*((C -32768)/32768))-267.34
#13T [°C]=((600/1.32)*((C -32768)/32768))-263.07
#16T [°C]=((600/1.32)*((C -32768)/32768))-271.52
#18 T [°C]=((600/1.32)*((C -32768)/32768))-272.34
#20 T [°C]=((600/1.32)*((C -32768)/32768))-266.00

6.4 Calibration of optical sensors

The optical sensor is calibrated for colour of the leaves and ambient light intensity & contrast & colour via software. Images are taken and the various parameters of the image quality are modified manually inside software. The software is calibrated for a certain focusing distance between the photo camera to plant and also distance from between the cameras. The focusing distance is dependent on the lens on the camera and its number is written on the lens.

The following must not change during measurements:

- The amount of light and position of the light source;
- The position of the camera, the aspect and the focus of the lens;
- The exposition (the duration of the camera shutter);
- The aperture of the lens;

This ambient light intensity & contrast have to be kept constant during all the measurements. If some of the parameters change (e.g. leave colour from green to red) then new calibration has to be made.

The utilization of the software in manual mode is as following:

Keyboard shortcuts for uEyeDualCam.exe

ctrl-N Open a new camera.
ctrl-TAB Switch frame - makes the other frame active.
alt-W S Swap frames vertically.
alt-W P Load preset parameters for the active frame.
alt-W V Tile the open frames side by side.
alt-W G Extract the green content for the active frame.
alt-W C Stacks all frames in the center;
use ctrl-TAB to switch between the frames.

Preferred sequence for camera operation using uEyeDualCam.exe

1) Open the first camera (ctrl-N).
2) Open the second camera (ctrl-N).
3) When both have opened an image, press the "Freeze Video" button.
4) Press button "Preset - Size and Color".
5) Tile images (window-frames) side-by-side (alt-W V).
6) If camera 4002890992 is on the left-hand side, swap images (alt-W S).

7) Resume - press the "Live Video" button. Images should update real-time now.
8) Position the scene as desired.
9) Take a snapshot (freeze) using the button "Manual Trigger - Freeze Video".
10) Repeat step 9) until the time-stamps become identical on both images.
11) The images are now simultaneous; use button "Save Pictures".

12) For each new scene, repeat from step 7).

Extracting the green colour content

21) Select / activate one of the color cameras.
22) Take a snapshot (freeze) using the button "Manual Trigger - Freeze Video".
23) Press button "Extract Green Color" (works only on the active frame).
24) Note the green content message in the status bar.
25) Optionally, use button "Save Pictures" (works on all open frames).

MAINTENANCE

Camera colour-adjustment/equalization using uEyeDualCam.exe:

A. Ensure steps 1)-4) are completed.
B. Place the two frames stacked in the centre (alt-W C).
C. The "Properties" button opens a tab-menu for the active camera.
D. Adjust the parameters in the "Image" tab and accept with "OK".
E. Compare the images in "Live Video" mode, by switching between them (ctrl-TAB).

Usage of the `HeightMap.exe` standalone application {#HeightMap_exe_HOWTO}
==========

General information
Each image `<filename>.png` should be accompanied by an `<filename>.info file. The respective <filename>` consists of the Date, Time, and CameraSerialNumber.

The `<filename>.info` file contains text with information needed in the processing:
- the current revision of the software that generated the image
- the chosen Area-of-Interest (AOI) within the camera field of view
- the pixel-offset between the cameras in a given pair
- the selected HSV parameters for extraction of the foliage content, named Hmax, Hmin, Smax, Smin, Vmax, Vmin, and can be edited manually.

HeightMap normal processing sequence {#HeightMap_normal_sequence}
1. After starting up the `HeightMap.exe`, choose the folder/directory containing the images with the *File->Select Directory* menu item. The chosen folder should appear in the field *Working directory* at the bottom of the window.

2. Select one of the desired images with the *File->Open* menu item.
The application automatically computes the plant/green content in each image, based on the data in the `<filename>.info` files.
The foliage-only images are displayed side by side, and the percentage is shown in the *Plant content* fields.
NB: A pair of images must exist, tagged with the same time-stamp.

3. Select the item *Display plant-pixels only...* from the pull-down menu and press the *Display* button. A new window called *Figure 1* shows the data contained in memory.

4. Select the item *Display height-map...* from the pull-down menu and press the *Display* button. The mapping process can be seen in Figure 1. Wait until the counter *Remaining levels* reaches 0.

5. Select the item *Display height-histogram for chosen region...* from the pull-down menu and press the *Display* button. The histogram is then shown in a new window named *Figure 2*.

In the absence of a calibration file named `init-data\conversion_formula.m`, only the *Mean unnormalized height* is shown, measured in pixels.
In the presence of `init-data\conversion_formula.m`, also the computed *Mean normalized height* is shown accordingly.
NB: `conversion_formula.m` contains text in the form of a function: `y = a + b*x + c*x^2 + ...`, which should be derived by the user by analyzing the growth of a typical plant over time.

6. The procedure can be repeated from Step 2) for all image pairs in the chosen *Working directory*.
The item *Check image alignment...* from the pull-down menu is useful for demonstration purposes. The process of plant-pixel correlation can be visualized in a separate window called *Figure 3*.

HeightMap processing with changed HSV parameters

Occasionally, the `Zephyr Scheduler` user may accidentally choose the wrong `.hsv` file for a given plant type.

While the `Zephyr Scheduler` will save the complete image information in `<filename>.png`, the `<filename>.info` files will contain the wrong HSV color parameterization.

At a later time, the user may edit the `<filename>.info` files with the proper values for Hmax, Hmin, Smax, Smin, Vmax, and Vmin. At that point, the sequence above can be repeated with the new HSV colour parameters:

1. Steps 1)-2) allow recomputation of the plant/green content for a given image pair.
2. Steps 1)-6) allow also for complete re-computation of the height-map for a given image pair. Note that both `<filename>.info` files should be edited in that case.

6.5 Calibration of radiation sensor

The SQ-225 is an amplified quantum sensor that measures photosynthetically active radiation and is calibrated for use with electric lights. The sensor housing design features a fully potted, domed-shaped head making the sensor fully weatherproof and self-cleaning. Photosynthetically active radiation (PAR), or photosynthetic photon flux (PPF), is the wavelength range from 400 to 700 nanometers and is strongly correlated with plant growth. Gardeners, greenhouse managers, growth chamber users and salt-water aquarists measure PAR to insure optimal specimen health.

Figure 30: radiation sensor

Sensitivity: 2.0 mV per µmol m^{-2} s^{-1}
Calibration Factor: 0.5 µmol m^{-2} s^{-1} per mV (reciprocal of sensitivity)
Calibration Uncertainty: ± 5%
Measurement Repeatability: < 1%
Non-stability (Long-term Drift): < 2 % per year
Non-linearity: < 1 % (up to 2500 µmol m^{-2} s^{-1}; maximum PPF measurement is 2500 µmol m^{-2} s^{-1})
Response Time: < 1 ms
Field of View: 180°
Spectral Range: 410 nm to 655 nm
Directional (Cosine) Response: ± 5 % at 75° zenith angle
Temperature Response: 0.06 ± 0.06 % per C
Operating Environment: -40 to 70 C, 0 to 100 % relative humidity, Can be submerged in water up to depths of 30 m

7. Section 6 – Preventive Maintenance

7.1 The rotation system

Oil periodically the chain

7.2 Watering system

Refer to the following figure to clean the circulation pump and the immersion tank periodically (preferably after each growth cycle; clean the bottom grids of the shelves after each growth cycle.

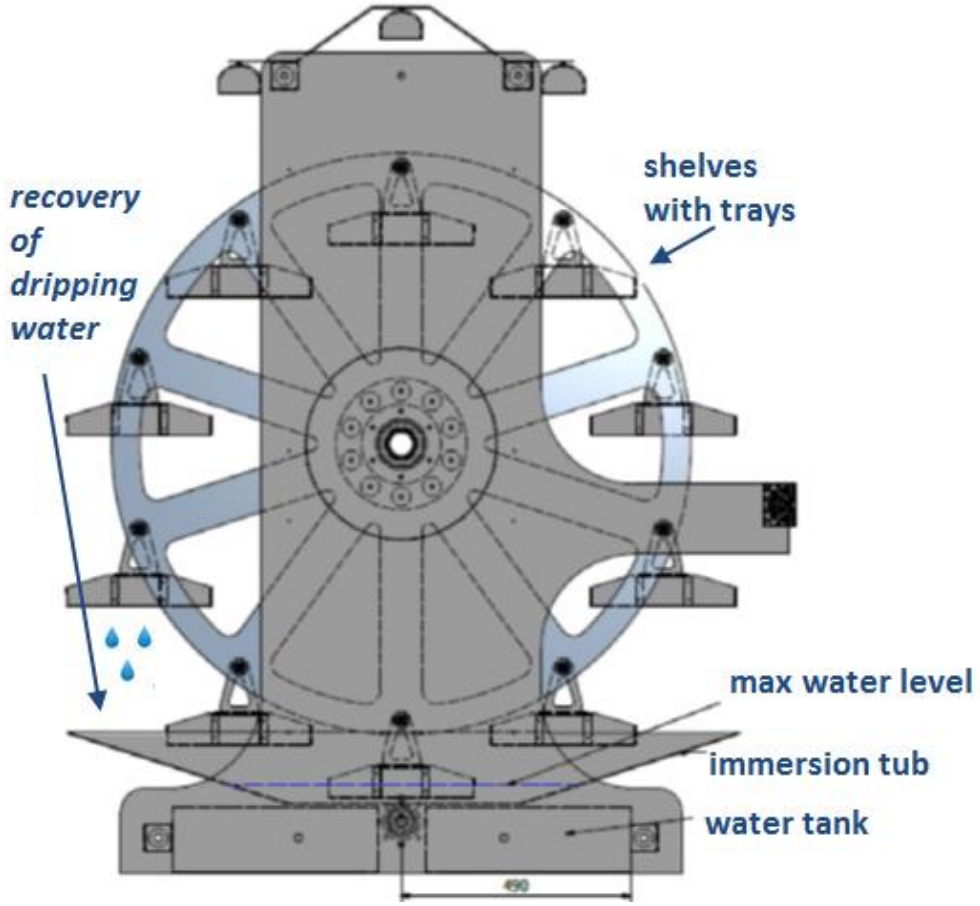


Figure 31: illustration of the watering sensor

7.3 Translation system

Clean with compressed air the track once a month;

7.4 Robotic arm

The only maintenance that must be done on a regular basis is the finger lubrication according to the following information.

Designation	Periodicity	Time needed	Procedure
Finger lubrication ensures optimal performance of the gripper and noise reduction.	Fingers should be lubricated every 6 months	30 minutes for total procedure (lubrication of the 3 fingers).	Refer to the Jaco maintenance guide in the appendix A

7.5 HVAC system

Check sections 2 and 3 sections in the PLUS 100 THR manual in Appendix B

7.6 Electrical system

Preventive maintenance for the electrical system

Solar systems require little maintenance as compared to other electrical systems such as diesel generators; however they are not maintenance free. Proper maintenance ensures the solar system life is preserved for as long as possible and the original conditions.

The system does not have any moving parts and therefore requires only minimal maintenance. The system owner should periodically (e.g. monthly) check that the system is still operating, this can be most easily done by either:

- Checking that the inverter and charge controller are operating (the green light is on in good weather conditions)
- Visual display shows an increased value over a period of a day

Note: At all times an authorised personnel should be available for general pattern and maintenance of the solar PV electrical system.

Solar Panel Maintenance:

The solar array (a number of solar panels connected together) is often thought to be maintenance free. However, occasional maintenance and inspection of the solar array must be performed to ensure the optimal use of the solar panels. This can be done by keeping the surface (glass) area of the module clean from any excess dirt.

- To remove a layer of dust and dirt from the modules, simply wash the panel with water. If the module has thick dirt or grime and bird droppings, which are harder to remove, wash with cold water and rub the panel surface with a sponge.

Battery maintenance:

The Zephyr unit comes with a well-structured and safely positioned batteries as shown in Figure below:

Figure 32: Batteries location

In the Zephyr unit the battery system is designed to keep the battery charged at all time for emergency backup requirement, the inverter and charge controller are set to offer longest backup time in the event of a grid failure, and the longest life for the batteries.

Additionally, the batteries should be regularly and carefully maintained to extend their useful life, by inspecting the state of charge on the display and cleaning periodically taking safety precautions.

Inverter/Battery Charger and Charger controller:

This component can be maintained by minimizing dust accumulation. A dry cloth should be used to wipe away any accumulated dirt/dust. A visual inspection should be done to ensure that all the indicators such as LED lights are working and that the wires leading to and from this device are not loose. Note that the charge controller should indicate that the system is charging when the sun is up. If not, contact the installer immediately.

Wiring and Connections:

Wiring installations should be checked for any cracks, breaks or deterioration in the insulation/conduits. Inspect panel boxes to ensure that they have not become a home for rodents and insects. Also inspect connections for any corrosion and/or burning. Switches should not spark when turned on or off. The following sections of conduit and wiring should be checked for any signs of damage:

- Solar panels to the charge controller
- Charge controller to the battery bank
- Inverter/charger to the battery bank
- Generator/Grid connection to Inverter/charger
- Inverter/charger and Generator to the AC outlets/load
- Battery bank to the DC outlets/load.

If damage is found, consult with the installer as soon as possible. All ground wires should be checked to ensure they are not broken. PV performance is increased with a long-term commitment to a preventative and predictive maintenance program.

7.7 LED Lamp

Designation	Periodicity	Time needed	Procedure
Cleaning of the luminaire plexi cover	Plexi should be cleaned every 2 months	2 minutes	Wipe the plexi with a clean cloth. Do not use any strong detergents!

7.8 Sensors

7.8.1 Optical sensor

Lenses should not be touched by hand or other sharp objects. Oil and debris from hands or from used lens tissue can stain or damage optical coatings. If it is not dirty, don't clean it. Handling optics increases their chances of getting dirty or damaged, so one should clean optics only when necessary.

Dusting is always the first step in cleaning optics. Wiping a dusty optic is like cleaning it with sandpaper. So always dust with a canned air duster, compressed and filtered air, or nitrogen before wiping any optic. If the dusted optic has no visible stains after one dust it, then it is done. If it is still not clean, use reagent- or spectrophotometric-grade solvent and special tissue for optical lens. The grade solvent should be a mix of 60% acetone and 40% methanol. Always use acetone-impenetrable gloves when using acetone.

7.8.2 Soil sensor

The electrodes from the soil sensors can be cleaned gently with a soft cloth without liquids when beginning a new series of measurements to remove the remaining soil particles.

8. Section 7 – Electrical Schematics

8.1 Electrical system

Electrical system schematic for the PV system is shown in the figure below:

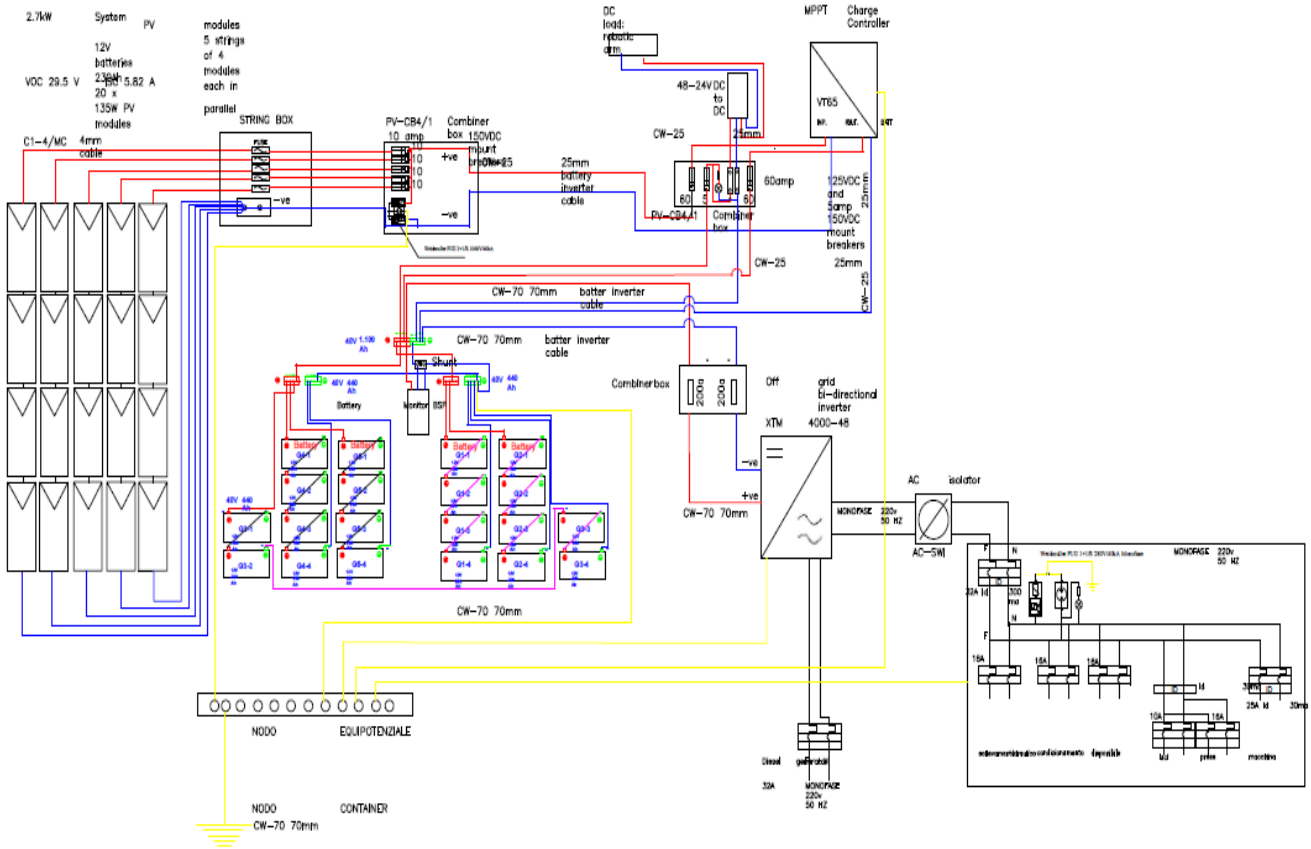


Figure 33: Wiring of Electrical system

8.2 Main controller

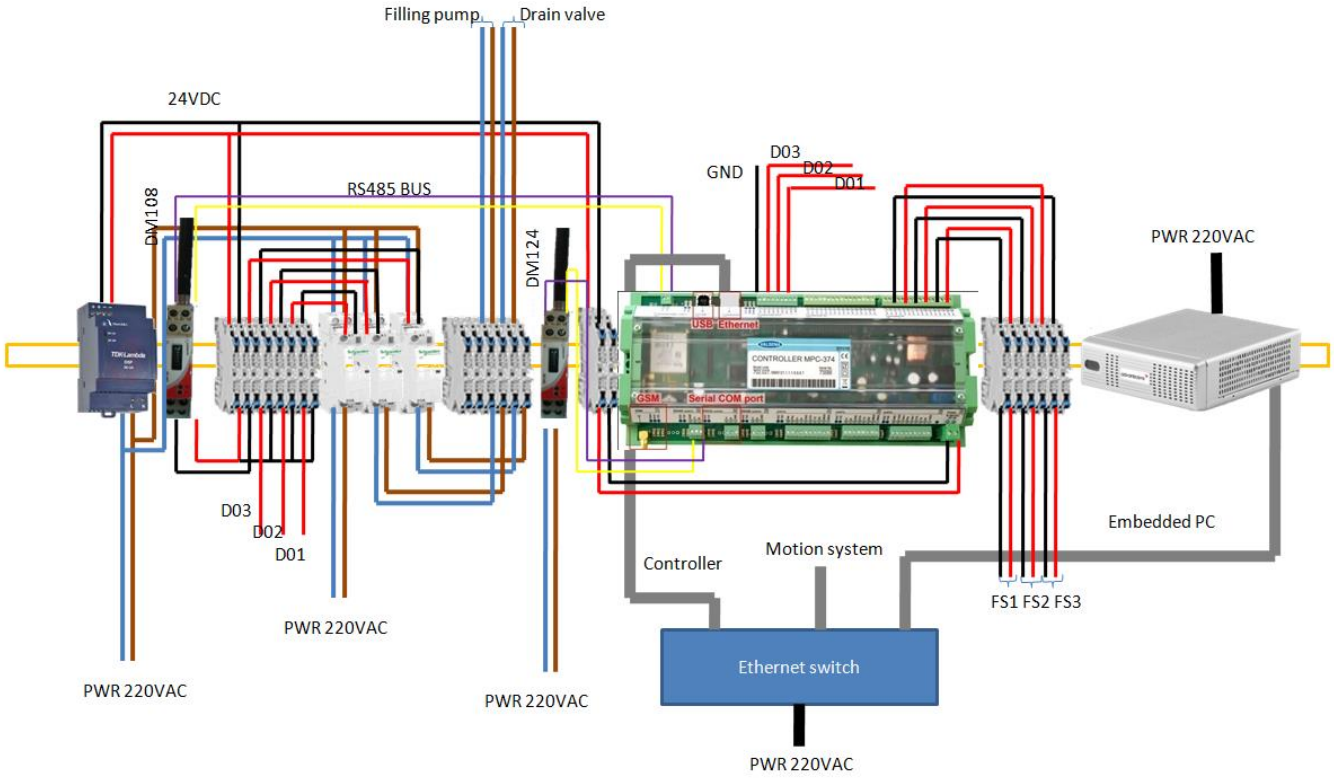


Figure 34: Wiring of the main controller

Main components:

- Radio transceivers 868MZ /2.4Ghz
- MPC controller
- Embedded PC
- Ethernet switch

8.3 Growth Chamber

8.3.1 Watering system

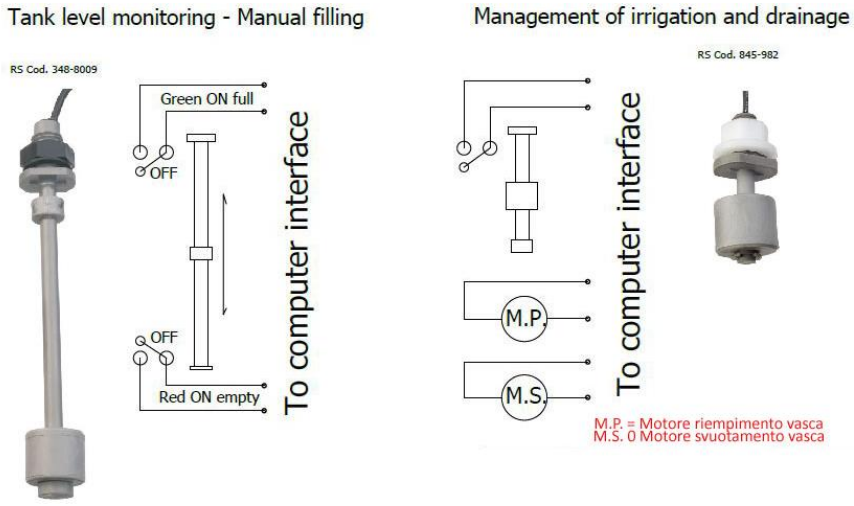
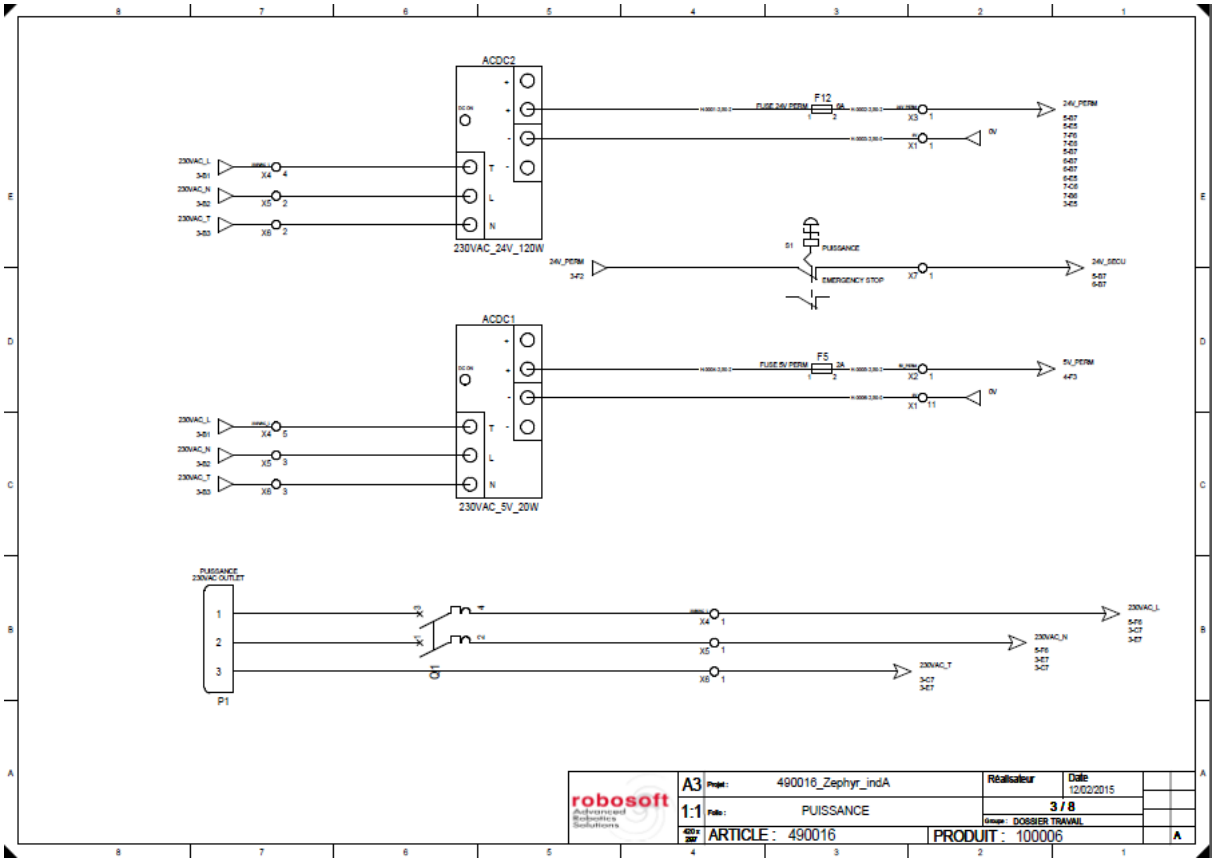
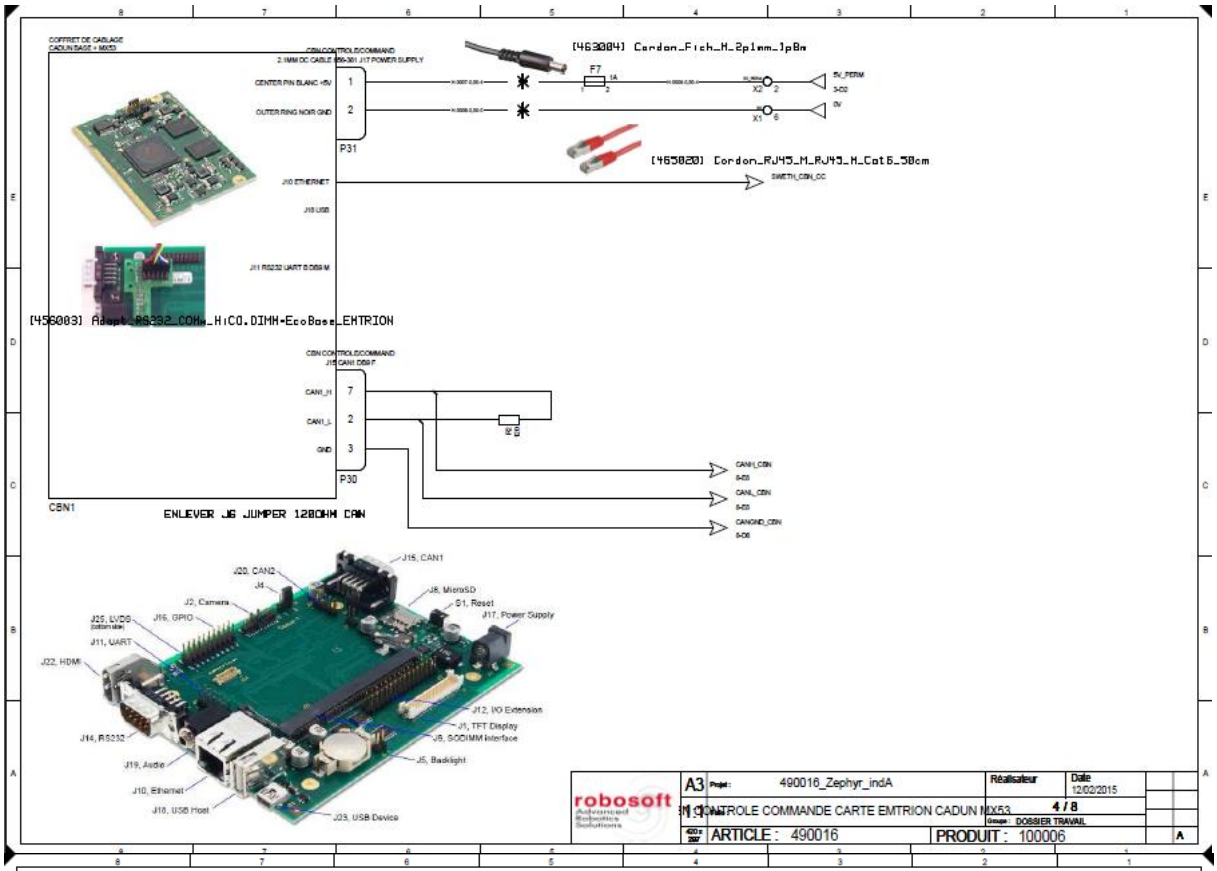


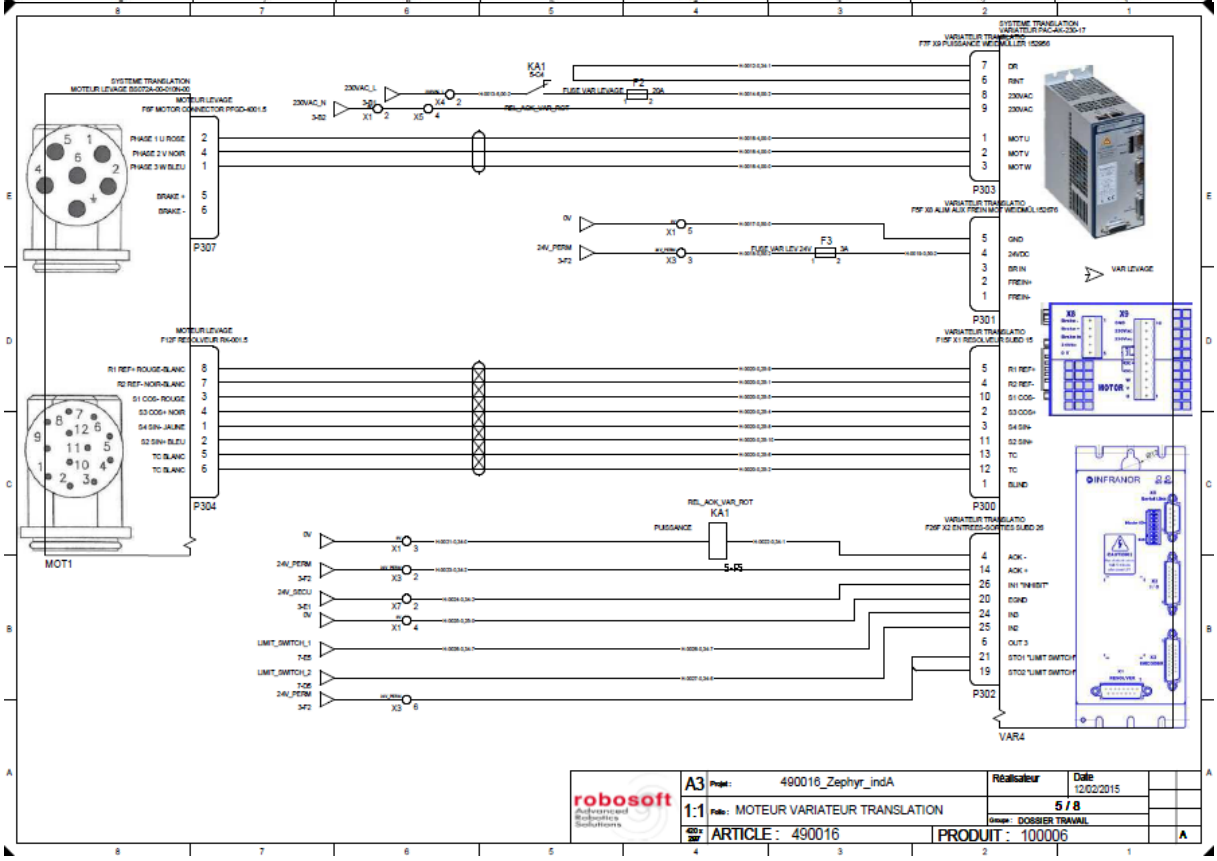
Figure 35: Watering system wiring

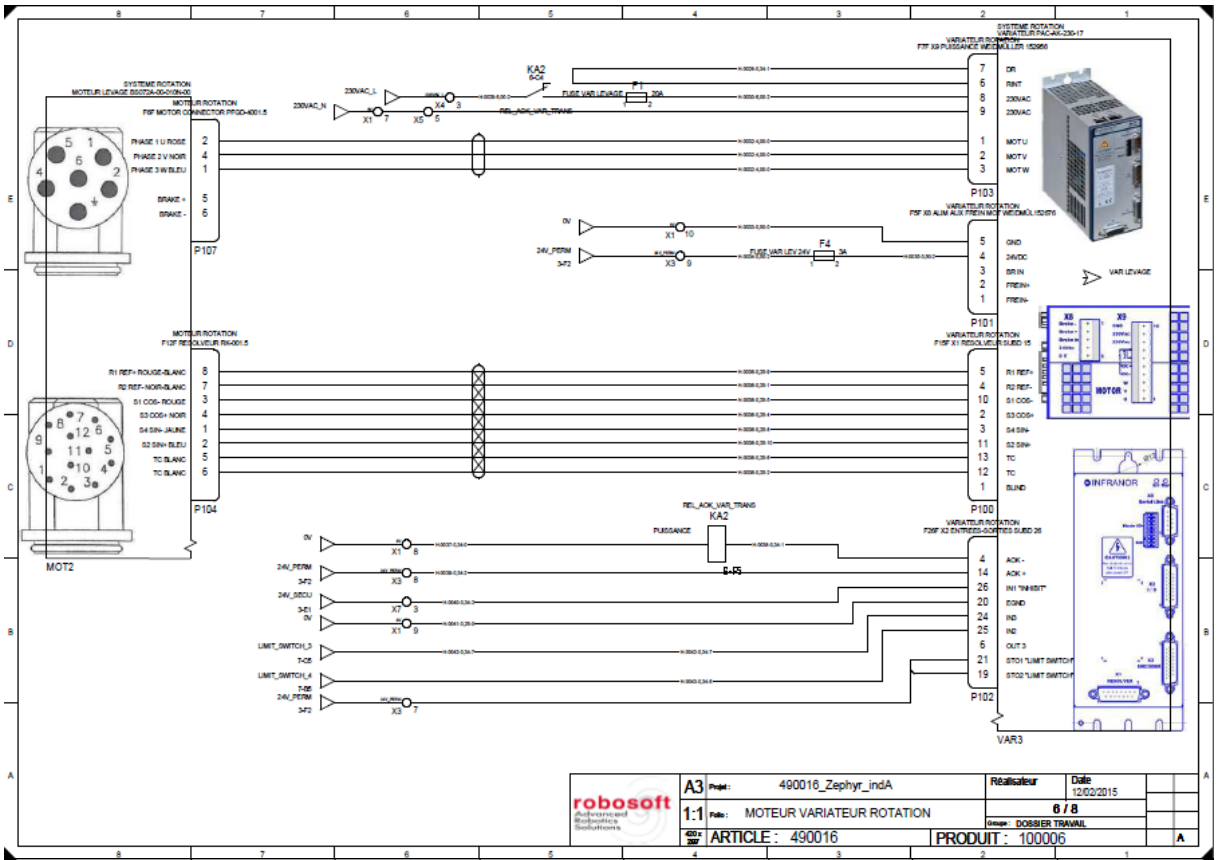
Details in the appendix B

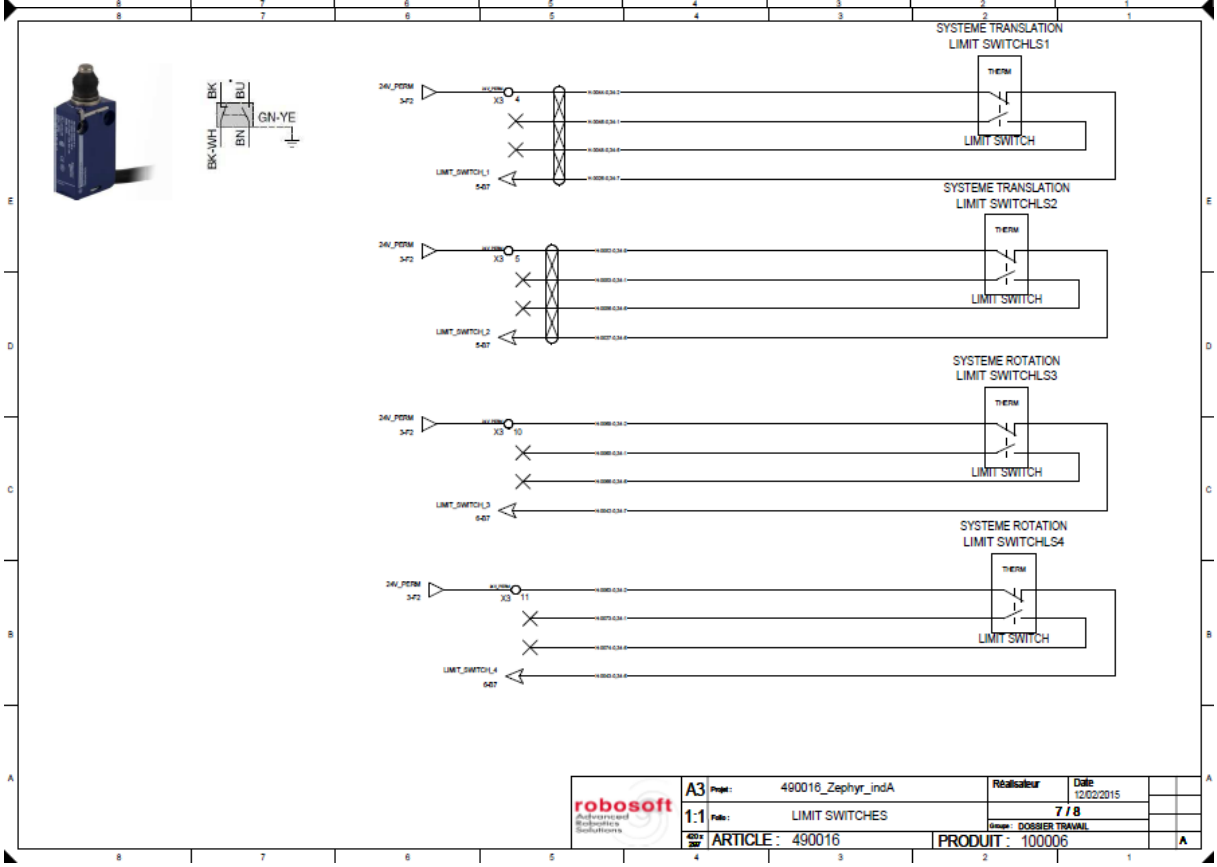
8.3.2 Rotation, translation and robotic arm




[463004] Cordon_Fich_M_2p1mm_1pBm
[465020] Cordon_RJ45_M_RJ45_M_Cat6_50cm
[458003] Adapt_RS232_COM_HiCO.DIMM-EcoBase_EMTRION
CBN1
ENLEVER JB JUMPER 120OHM CAN
robosoft
490016_Zephyr_indA
CONTROLE COMMANDE CARTE EMTRION CADUN MX53
4 / 8
ARTICLE : 490016
PRODUIT : 100006


P307
P303
P301
P304
P300
P302
MOT1
VAR4
robosoft
490016_Zephyr_indA
MOTEUR VARIATEUR TRANSLATION
5 / 8
ARTICLE : 490016
PRODUIT : 100006


P103
P107
P101
P104
P100
P102
MOT2
VAR3
INFRANOR
robosoft
A3
490016_Zephyr_indA
1:1
MOTEUR VARIATEUR ROTATION
ARTICLE : 490016
PRODUIT : 100006
6 / 8
DOSSIER TRAVAIL
12/02/2015


SYSTEME TRANSLATION
LIMIT SWITCHLS1
SYSTEME TRANSLATION
LIMIT SWITCHLS2
SYSTEME ROTATION
LIMIT SWITCHLS3
SYSTEME ROTATION
LIMIT SWITCHLS4
LIMIT SWITCH
BK
BU
GN-YE
BK-WH
BN
robosoft
A3
490016_Zephyr_indA
1:1
LIMIT SWITCHES
ARTICLE : 490016
PRODUIT : 100006
7 / 8
DOSSIER TRAVAIL
12/02/2015

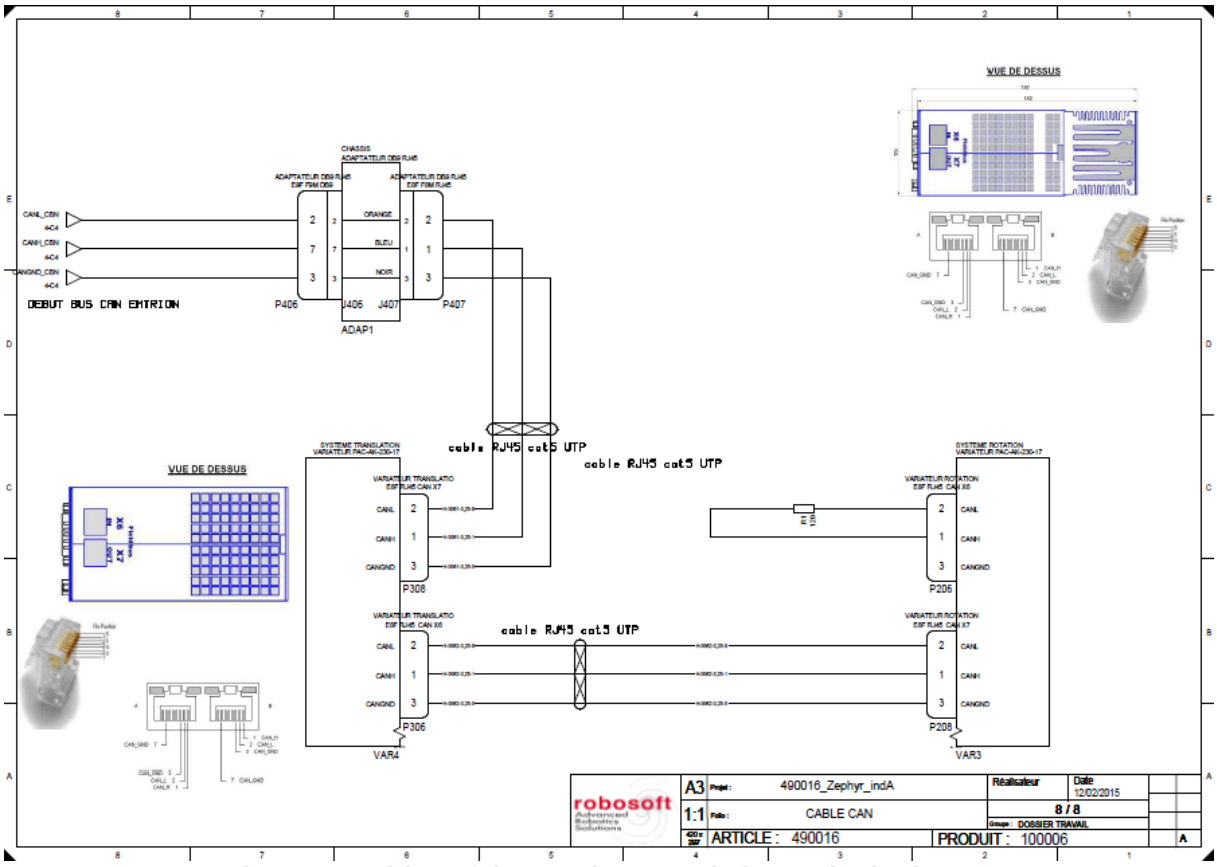


Figure 36: Wiring of the rotation, translation and robotic arm

8.3.3 Inspection sensors

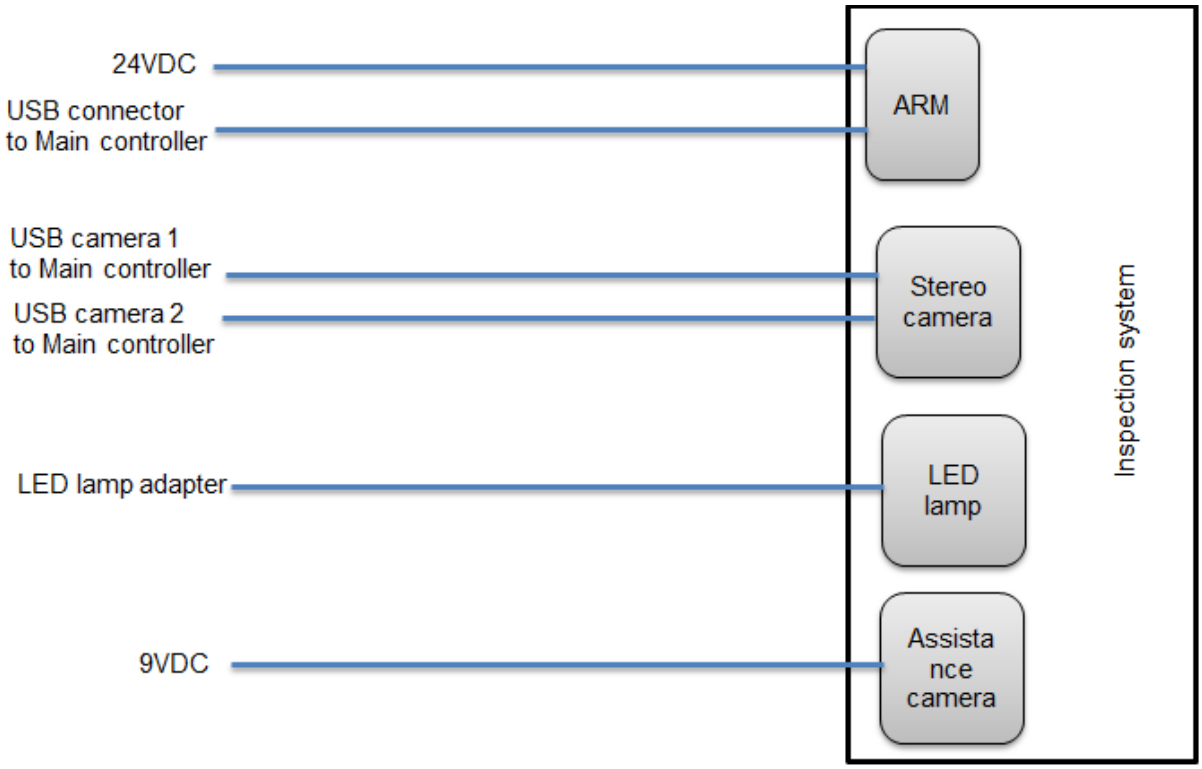


Figure 37: Inspection sensors wiring

8.4 HVAC

1 2 3 4

5

1 General power on/off
2 Led indicating power on
3 Cooling system on/off
4 heating system on/off
5 Temperature/Humidity controller (see the

See section A2 of the PLUS 100 THR manual
l

9. Section 8 – Troubleshooting

The following table summarise the list of possible problem, possible cause and possible solutions for each problem

Problem	Possible causes	Solutions
Rotation stops to turn	Emergency stop activated, Motor overheated, connector(s) removed,	Check the emergency stop status, the status of the motion controller (refer to Motion controller manual in the appendix A)
Bad initialisation of the rotation during start-up	Problem with reference switch	Check the reference switch
Translation stops to move	Emergency stop activated, Motor overheated, connector(s) removed,	Check the emergency stop status, the status of the motion controller (refer to Motion controller manual in the appendix A)
Robotic arm stops to move	Power or control connector removed	Check both connectors Use Jaco soft to proceed with arm diagnosis (refer to Jaco arm User's Manual in the appendix A
HVAC System	See chapter 7 of the PLUS 100 THR manual	
Negative or spikes in signal from soil sensor	(a) Not good contact between sensor electrodes and soil; (b) Measurements outside the designed interval of functioning.	(a) Properly inserting of electrodes into soil. (b) Wait until the defined measurement interval.
Not correct values for greenness and/or plant height	Not correct settings for optical / camera sensor	Follow the instructions for installation and don't modify parameters during measurements
Luminaire does not operate after installation	Connectors are not connected properly	Check the connections

Luminaire does not light up or lights up partially	LED light source malfunction	Check power connections. If it does not help, please contact distributor for customer service.
The power to the electrical unit stops	No enough charge left in the battery/no enough power from sun	Check the RCC display for battery level and State of Charge (SOC), if less than 30% connect the external generator to the Zephyr unit (as per the Inverter manual in Appendix C)
PV array performance decrease	Wiring problems/shading or soiling effects	Check all wiring, switches, fuses and circuit breakers. On the PV array look for shadding from nearby trees or leaves and dirt deposited on the panels (shading on the panel array can reduce the overall performance by 5%) Note: All the checks should be performed by authorised personnel at all times.
The inverter is not producing the correct output	if the inverter is not producing the right amount of power there may be a number of problems: • blown fuse • tripped breaker • broken wires	First use the voltmeter and dc ammeter to check and record the inverter's operating dc input voltage and current level. On the ac side, use the AC multimeter to check the inverter's output voltage and current levels. Once confirmed consult the installation company for repair or replacement of default fuses and or broken wires inside the inverter.

10. Section 9 – Spare Parts Replacement

10.1 Legend

	Operation time needed.	
	Difficulty level :	
		Easy.
		Average level, care must be taken.
		Difficult, take special care in this operation.
	Number of person needed.	
	Needed tools.	

10.2 Electrical system

The electrical system comes with products on warranty from individual components which are transferred to the owner.

10.2.1 Installation and Wiring

- 5 year electrical system full covered parts and labour warranty on the installed system, inspection.

10.2.2 Solar PV Modules

- 2 year PV modules product warranty,

10.2.3 Inverter/Charge Controller

- 5 year Inverter/Charge controller product warranty

10.2.4 Battery

- 2 year product warranty

All the electrical equipment comes with a warranty and should be replaced by the experienced and qualified installer/technician.

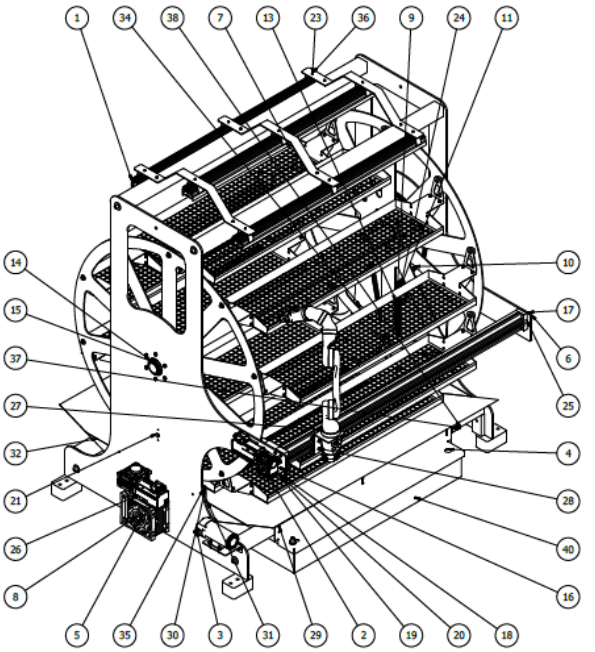
10.3 Growth chamber

10.3.1 Mechanical frame

The following picture shows the list of the mechanical parts with their reference respect to the whole frame; with the exception of the shelves only, that can be easily removed and replaced, all the other parts should be requested to the producer and replaced by an authorized technician . The drawings in the appendix B show the detail of each mechanical

ELENCO PARTI

ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	3	VALOYA	LAMPADA LED
2	1	ZPHR-107-7000	ASSIEME RID. ASSE X
3	1	ZPHR-106-6000	ASSIEME POMPA
4	1	ZPHR-102-2000	ASSIEME SERBATOIO
5	1	CWMI-4075-A13-63B14-214	MOTORIDUTTORE VF/VF
6	1	ZPHR-101-1000	ASSIEME STRUTTURA
7	1	ZPHR-105-5000	ASSIEME TAMBURO
8	1	ZPHR-104-4000	ASSIEME ASSE PRINCIPALE
9	2	Catena a rulli	CATENA A RULLI
10	2	Ruota dentata catena a rulli2	CORONA 100Z
11	2	Ruota dentata catena a rulli3	PIGNONE 15Z
12	2	Ruota dentata catena a rulli1	PIGNONE 15Z
13	2	RCT-T1	TENDICATENA
14	2	ISO 2982-2 - 60 x 73	Dadi di fissaggio e dispositivi di fissaggio - Quote - Rondelle di fissaggio di sicurezza con linguetta di fermo diritta
15	2	ISO 2982 - M60 x 2 x 73	Dadi di fissaggio e dispositivi di fissaggio - Quote - Dadi di fissaggio (4 intagli)
16	8	ISO 7092 - ST 6 - 140 HV	Rondelle piatte - Serie piccola - Grado prodotto A
17	8	ISO 4017 - M6 x 16	Viti a testa esagonale
18	28	ISO 7092 - ST 8 - 140 HV	Rondelle piatte - Serie piccola - Grado prodotto A
19	4	ISO 4017 - M8 x 25	Viti a testa esagonale
20	4	ISO 4032 - M8	Dadi esagonali, stile 1 - Gradi prodotto A e B
21	2	ISO 4017 - M10 x 30	Viti a testa esagonale
22	20	ISO 4017 - M8 x 20	Viti a testa esagonale
23	9	ISO 7092 - ST 4 - 140 HV	Rondelle piatte - Serie piccola - Grado prodotto A
24	2	DIN 625 SKF - SKF 6201-RS1	Cuscinetti a sfere con scanalatura profonda a fila singola con guarnizione RS1 SKF
25	1	NL106RC	GUIDA A RICIRCOLO
26	1	MAVILOR-BLS-072	MOTORE MAVILOR
27	1	ZPHR-103-3000	BRACCIO ROBOTICO
28	4	ISO 4762 - M8 x 16	Vite con esagono incassato
29	1	ZPHR-108-8000	ASSIEME FERMA SERBATOIO
30	1	ZPHR-001-0002	STAFFA SENSORE VASCA
31	1	SensVASCA	SENSORE VASCA
32	1	ZPHR-001-0001	VASCA IMMERSIONE
33	1	ZPHR-108-8001	FERMA SERBATOIO
34	2	ZPHR-109-9000	ASSIEME SUPPORTO VASCA
35	2	ZPHR-110-1000	ASSIEME SUPPORTO VASCA
36	9	ZPHR-111-1100	ASSIEME STAFFA LAMPADA
37	1	ZPHR-001-0003	SUPPORTO POMPA
38	1	ZPHR-001-0004	OMEGA POMPA
39	1	ISO 4762 - M5 x 35	Vite con esagono incassato
40	1	ISO 7090 - 5 - 140 HV	Rondelle piatte, smussate - Serie normale - Grado prodotto A



	NAME	DATE
DRAWN	Co.Met.Art	23/11/2015
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ± X.X°
2 PL ± X.XX 3 PL ±X.XXX

Co.met Art

TITLE
ZEPHYR

SIZE	DWG NO	REV
A2	ZPHR-001-0000C	A

FILE NAME: ZPHR-001-0000C.dwg

SCALE:	WEIGHT:	SHEET 1 OF 1

part in d

10.3.1.1 Rotation motor replacement

ROTAZIONE
Motore "rotazione" Bruschless a: c.
Mavilor
Ty. BLS 072A.00.10N.00
Da ELCAM spa It.

10.3.1.2 Translation motor replacement

ROTAZIONE
Motore "rotazione" Bruschless a: c.
Mavilor
Ty. BLS 072A.00.10N.00
Da ELCAM spa It.

10.3.1.3 Watering pump replacement

Pompa riempimento vasca irrigazione e svuotamento serbatoio per trasporto. Mod. 5843-2P02_8101; 230V; 60W da TECHMAGPM It.

10.3.1.4 Index switch replacement

10.3.2 LED Lamp replacement

10.3.2.1 Unpacking

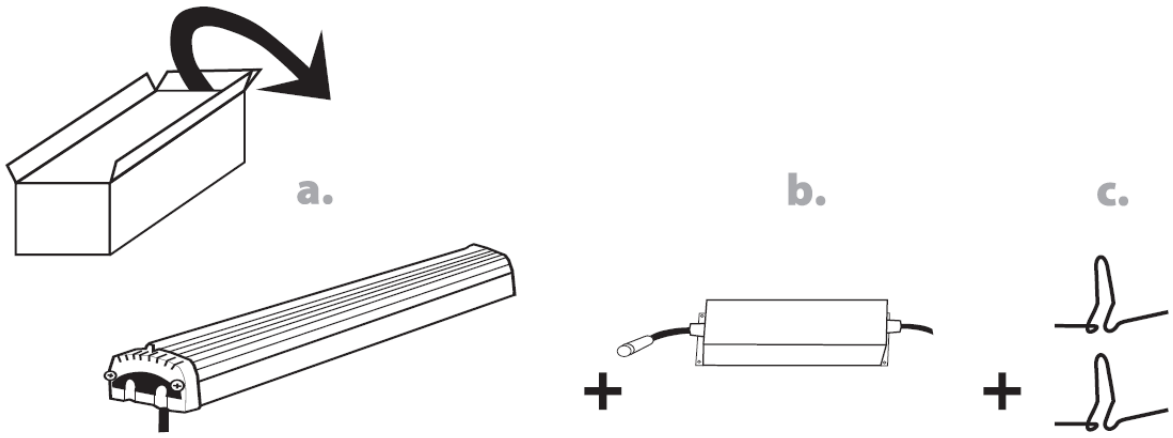


Figure 38: The LED lamp parts

a) luminaire
b) power supply unit
c) hanging device

10.3.2.2 Installation

Caution! Inappropriate installation may cause injury to persons and damage to the lamp. Deviation from the instructions may result in electric shock or an electrical hazard.
If the external cable or cord of this luminaire is damaged, it must only be replaced by the manufacturer or a service agent or similar qualified person, in order to avoid a hazard.

If you notice that any part of this luminaire is damaged, please contact Valoya.

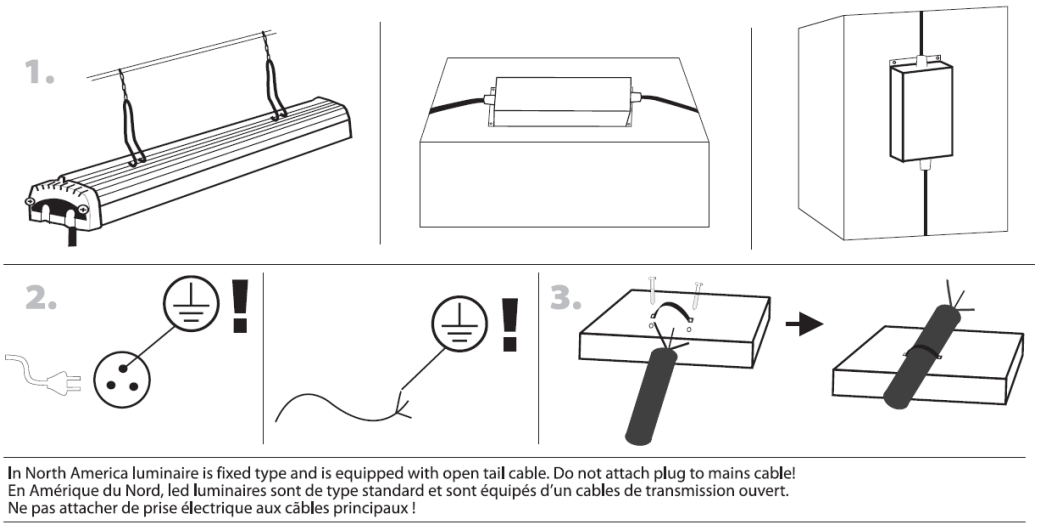


Figure 39: LED lamp equipment

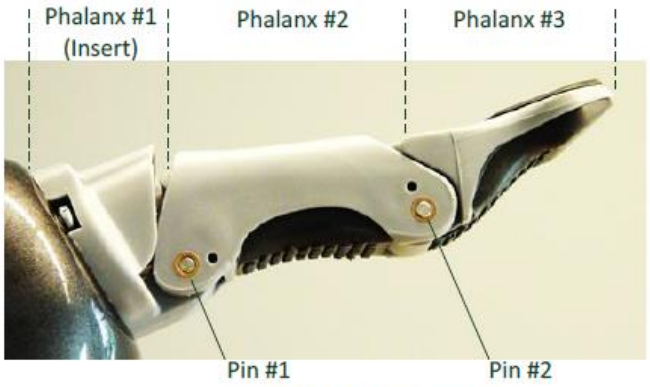
1) hanging options
2) grounded power connection only
3) if the luminaire is provided with an open tail cable, the connection to the branch circuit must be equipped with proper strain relief

10.3.3 Robotic arm

10.3.3.1 Finger replacement

10 min		1
Allen Key 2mm.		

Finger parts identification:



JACO's finger parts ID

Figure 40: Arm finger parts

PROCEDURE

JACO must be powered and connected to a joystick to complete procedure.

- Remove obsolete finger as following:
    - Remove pin #1 of finger by pushing it out with the 2mm Allen Key
    - Remove the 4 corners cap screws holding phalanx #1 with 2mm Allen key
    - Unscrew the finger from the lead screw
- Using dry tissue, remove old grease from finger motor's lead screw and remaining grease on the limit switch located at the bottom of the finger motor as shown in the following Figure;

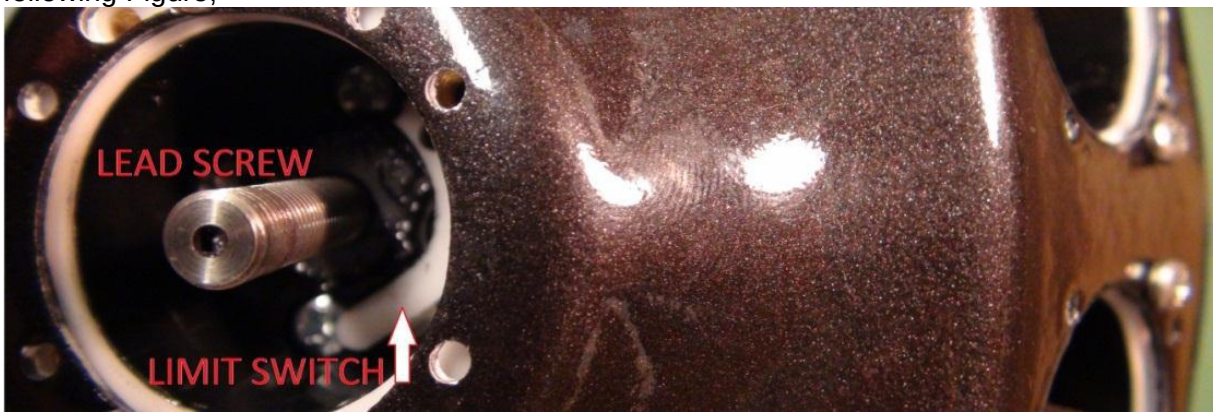


Figure 41: Arm finger attachment base

Do not use thinner

- With 2mm Allen key, gently push out pin #1 of the new finger;
- Add new grease (about grain of rice) in phalanx #1 of the new finger (brass threads, plastic insert);
- Add new grease (about a grain of rice) on the bottom of the lead screw on a 7mm height;
- Install new finger as following:
    - Lubricate the finger
    - Place the finger's insert on the finger motor's lead screw and, using joystick, open the fingers until the insert is fully engaged and the lead screw is visible outside the insert;
    - Add a light amount of Loctite 242 on 3 mm at end of each cap screw;
    - Screw finger in place
    - Realign all holes of pin #1 and gently push it back in
    - Make 5 open/close cycles to make sure the finger opens and closes properly

10.3.3.2 Motor replacement

Refer to the Appendix A

11. Appendix A – Arm and motors controllers guides

Jaco Arm Maintenance Guide.pdf
jaco-arm-user-guide.pdf
Motion controller manual.pdf

12. Appendix B – Growth chamber drawing and HVAC user guide

Float switch 1 - lower tank.pdf
Float switch 2 - immersion tank.pdf
Manuale Regolatore Plus 100 THR.pdf
Pump 1 - immersion tank filling.pdf
SensoriMePompe.pdf
ZE04PDF.pdf
ZPHR-001-0000A.pdf
ZPHR-001-0000B.pdf
ZPHR-001-0000C.pdf
ZPHR-001-0001.pdf
ZPHR-101-1000.pdf
ZPHR-102-2000.pdf
ZPHR-103-3000.pdf
ZPHR-104-4000.pdf
ZPHR-106-6000-1.pdf
ZPHR-107-7000.pdf
ZPHR-108-8000.pdf
ZPHR-111-1100.pdf

13. Appendix C – Power system guides

Exergy Safety Manual ZEPHYR (IT).pdf
Manuel RCC V4.4.0_EN.pdf
Xtender & Charge Controller User manual.pdf