Horti Lighting Protocol

Version 1.1.0
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Change Management

Version	Date	Author(s)	Changes
0.9	5 April 2023	Hoogendoorn, Priva, Ridder	Draft version for comments lamp suppliers
1.0	1 May 2023	Hoogendoorn, Priva, Ridder	Final version based on feedback lamp suppliers
1.0.1	12 June 2023	Hoogendoorn, Priva, Ridder	Mistake corrected with kW vs kWh
1.0.2	18 December 2023	Hoogendoorn, Priva, Ridder	Clarified working ELC module verification mechanism
1.0.3	22 March 2024	Hoogendoorn, Priva, Ridder	Clarified working ELC module verification mechanism; minor clarifications.
1.1.0	26 May 2025	Hoogendoorn, Priva, Ridder	Simplified working ELC module verification mechanism; Renamed module Universal Measurements to Universal Inputs; Added module Universal Outputs; Added module Preferred Setpoints; minor clarifications.

Glossary

Definition	
Automation system	Horticulture process control automation system
Channels	Via Channels information can be transmitted over serial lines.
Control area	A defined area controlled as a whole by the Automation system.
General Settings	General settings to read information of the Lighting system or set certain setting of the Lighting system.
Horticulture process control automation system	The system to automatically control a wide range of processes in the greenhouse.
Horticulture Lighting Protocol (HLP)	Description of a Modbus based interface to connect Horticulture lighting systems to Horticulture process control automation systems.
(Horticulture) lighting system	The gateway and network of the lighting system in the greenhouse.
Modbus register	The Modbus registers contain process values used to control the Control areas.
Module	The Protocol is set up modular to meet the needs of all kinds of Lighting system technologies. The modules are defined in article 3.2.
Protocol	Horticulture Lighting Protocol (HLP)
Verification register	Via these registers a spectral composition can be verified.
Spectral composition	Sometimes referred to as recipe, set of setpoints for multiple channels or colors without a definition of time.

Table of Contents

1. Horticulture Lighting Protocol (HLP)

1.1. The Horticulture Lighting Protocol (HLP), hereafter named 'Protocol', describes a Modbus based interface to connect Horticulture lighting systems, hereafter named 'Lighting systems', to Horticulture process control automation systems, hereafter named 'Automation systems'.

2. System architecture

2.1. The Protocol describes how the Lighting system and the Automation system communicate. The Protocol assumes the Lighting system functions as Modbus slave and the Automation system as Modbus master.

2.2. Automation system → Ethernet/RS-485 → Lighting system Gateway → Lighting system network.

3. Modules

3.1. The Protocol is set up modular to meet the needs of all kinds of Lighting system technologies. The most basic way to use the Protocol is to only support the base functionality of communicating setpoints per Control area per channel.

3.2. There are six modules to expand on that functionality:

I. Module System status – Provide feedback to the Automation system about the status of the Lighting system.

II. Module Power – Provide feedback about the actual power usage of the luminaires.

III. Module Exact Light Control – Makes it possible to control the exact output, per spectrum of a Control area in µmol/s (or µmol/s/m^2).

IV. Module Universal Inputs – Makes up to ten free to use inputs (from the perspective of the Automation system) per Control area available. The Lighting system manufacturer must provide documentation of the content of the registers.

V. Module Universal Outputs – Makes up to ten free to use outputs (from the perspective of the Automation system) per Control area available. The Lighting system manufacturer must provide documentation of the content of the registers.

VI. Module Preferred setpoints – Provides the option to the automation system to read a (by the lighting system) preferred setpoint per channel and write a spectral composition number and a dimming percentage per control area to the lighting system. The module preferred setpoints provides the option for the Lighting system to influence or control the light output while leaving the Automation system in control of the power balance. This module can either be used on top of the basic implementation or the Module Exact Light Control implementation.

3.3. When a specific Module is supported, all parameters within this Module must be properly supported.

4. Options

4.1. The Protocol assumes Control areas (groups of lamps) with the same settings. There are 100 Control areas available in the Protocol design. Each control area can have up to eight Channels. Not all channels have to be used.

4.2. All individual Channels can be controlled by percentage or by µmol/s (or µmol/s/m^2). Control using a percentage is the easiest solution, this gives control over each physical Channel of the lamps. The percentage is assumed to be linear to the light output of the lamps.

4.3. In case precise control over the light spectrum is preferred, the lamps should be controlled using µmol/s/m^2 (or µmol/s). In this case verification of the spectral composition is necessary, the Protocol provides this option via Verification registers.

4.4. The verification process works in several successive steps. Additional parameters can be used and/or decisions can be added to improve the time to reach a desired set of setpoints.

1. The Automation system determines setpoints for all channels.
2. The Automation system writes the setpoints for all channels in use to the Verification Setpoint registers.
3. The Lighting systems checks these values against the lamp's capabilities. And makes changes to the value of the Verification Setpoint registers if necessary.
4. The Automation system reads back the Verification Setpoint registers.
5. The Automation system determines whether the read back setpoints are desired.
    a. If the read Verification Setpoint values are desired, the Automation system writes the desired setpoints for all channels. Or at least the values that have changed since the last verification cycle.
    Keep in mind that to trigger the calculation or execution of the setpoints the last configured channel must be written as well. Refer to paragraph 7.4.
    b. If the Automation system determines that the read back Verification Setpoints are not desired, the Automation system shall go back to step 1. Additional information such as the Verification Setpoint Maximum and Minimum can be used to determine a suitable set of Verification Setpoints.

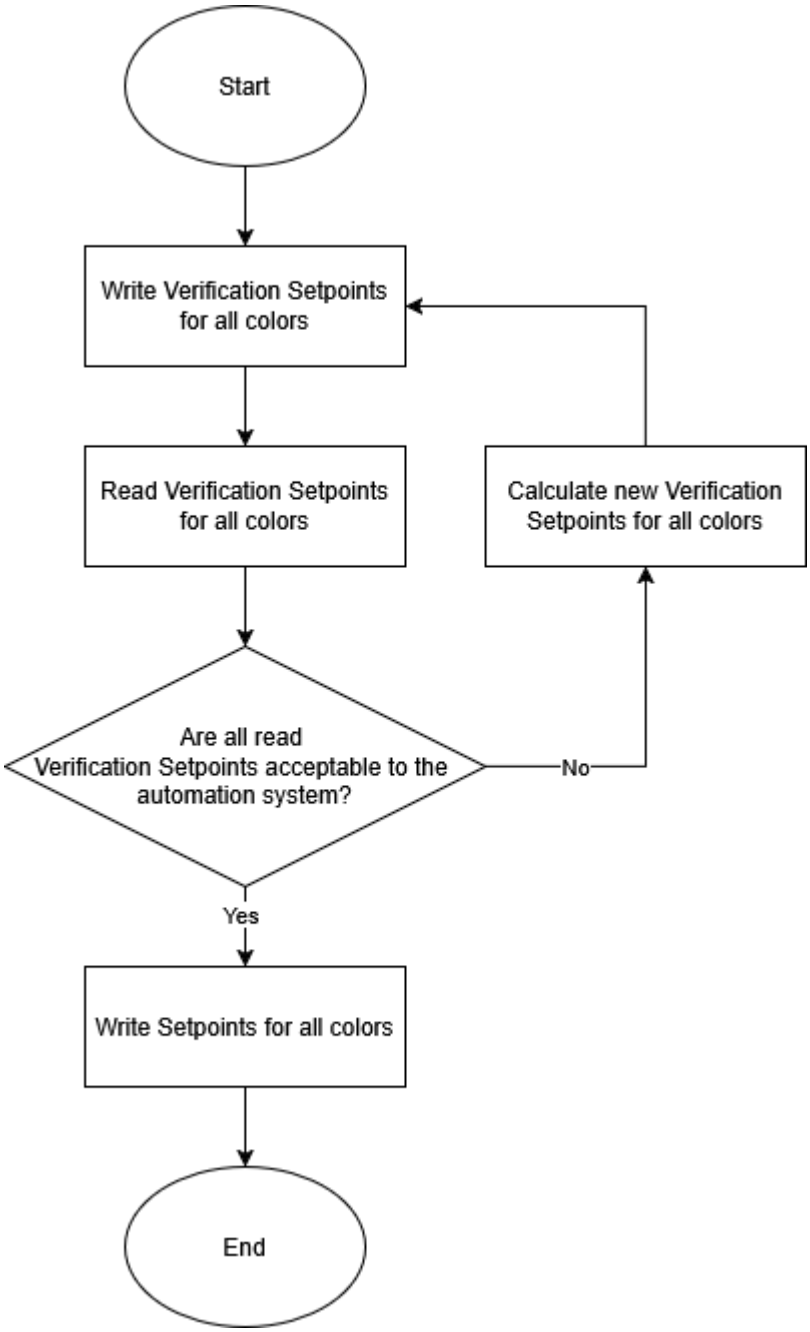

Figure 1 Module Exact Light Control communication from the perspective of the Automation System.

4.5. A gateway of the Lighting system that supports Module III (Exact Light Control) must calculate and update the Verification registers of a Control Area within 800 ms. Refer to paragraph 7.4.

4.6. When the luminaires have channels that influence each other it is required to either implement Module I (Module System status) or Module III (Module Exact Light Control) in order to provide proper feedback of the realized setpoints. In case implementation of Module I is chosen, when the automation system sets a setpoint

combination that cannot be realized, the lighting system should apply a setpoint that reflects the setpoint combination from the automation system the most. The automation system can read back the realized level from the lighting system.

4.7. Via the Module VI (Preferred setpoints) the Lighting System can communicate a preferred spectral composition. The Automation System can change these setpoints by activation a specific preset or scenario and an optional dimming percentage. The Automation System can apply this preferred spectral composition via the usual setpoint registers in percentage or using the exact light control module.

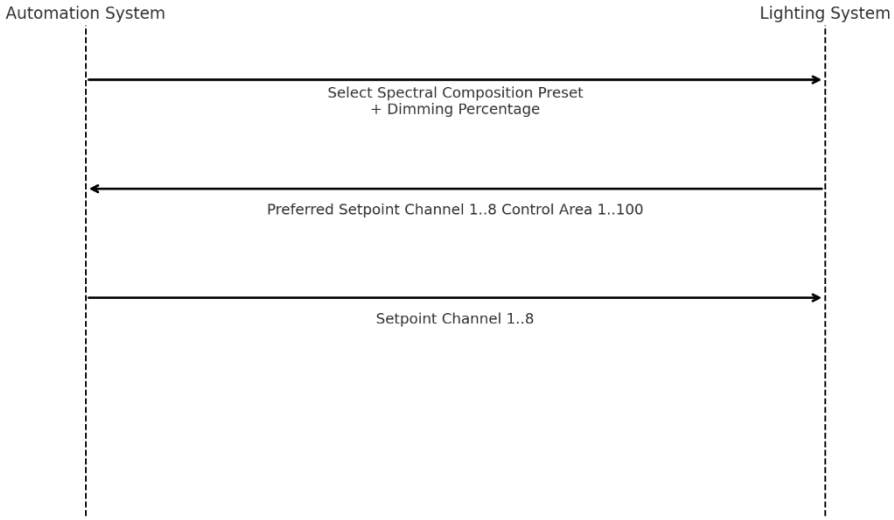

Figure 2 Module Preferred setpoints communication steps.

4.8. A gateway of the Lighting system that supports Module VI (Preferred Setpoints) must calculate and update the Preferred Setpoint registers of a Control Area within 800 ms after the last modification of the Spectral Composition Preset Dimming Percentage for that Control Area.

5. Modbus

5.1. The Protocol makes use of standard Modbus, either Modbus TCP or Modbus RTU via RS-485 half-duplex wiring. Parameters to control the Lighting systems are exchanged via 16-bit integer holding registers.

5.2. Keeping the large numbers of parameters in mind, Modbus TCP is preferred, especially for Lighting systems with a significant number of Control areas.

5.3. The Protocol uses big-endian byte order.

5.4. When using Modbus TCP, the gateway of the Lighting system uses a static IP address.

5.5. For the Modbus TCP interface port 502 is used.

5.6. The gateway of the Lighting system needs to support a well-documented and always available method to reset the Modbus and IP settings back to default and/or a method to approach the gateway locally at all times.

5.7. The protocol does not prescribe any security regulations to secure the Modbus communication. Therefore, the network between the automation system and the lighting system gateway should not have a connection to the internet or any internet connected network.

6. Modbus registers

6.1. There are two tables attached which describe the available Modbus registers. The first table with General settings provides the option to read information of the Lighting system or set certain settings of the Lighting system.

6.2. Modbus registers 50 up to and including 99 can be implemented freely by the Lighting system manufacturer.

6.3. The second table describes the Modbus registers containing process values, used to control the Control areas.

6.4. The last data in Modbus registers 0..99 and “Power on setpoint Control Area n Channel x” should be stored permanent in the HW of the lighting system. Repeated writes to these Modbus registers should not lead to excessive wear.

6.5. When a value is written to one of the General Settings registers it is required to apply the setting(s) manually. This can be achieved by writing a value to “Apply settings”. Al values written to Modbus registers from the General settings table will be applied at once.

6.6. As there are two options for physical connection with the gateway, Modbus RTU and Modbus TCP, the relevant parameters should be used, 20..24 or 30..43. If both interfaces are available both parameter ranges are active.

6.7. The Modbus registers used in HLP:

- Registers 0 ... 49 are used for current implementation for general settings.
- Registers 50...99 can be used for manufacturer specific implementation within current implementation.
- Registers 100...10899 are used for current implementation for parameter settings.
- Registers 10900...31999 are reserved for future expansion of the protocol.

6.8. There is a 1:1 relation between a channel and a color. Within a control area one channel represents one color or one spectrum. It is not allowed to use multiple channels for the same color.

7. Modbus timing

7.1. To be able to control large amounts of Control areas a decent Modbus response time should be achieved, less than 50ms.

7.2. No specific order of read or writes or ‘blocks of writes’ should be required, unless explicitly required by this standard.

7.3. A write action should not directly result in traffic over the network of the Lighting system. The gateway is responsible for regulating the timing and the amount of traffic over the (wireless) network of the Lighting system.

7.4. When using the module Exact Light Control only, it is expected that the setpoints of the channels have interdependencies. To make sure that a valid combination of setpoints has been communicated, the lighting system should assume that when the setpoint of the last channel in use of a control area has been written, all setpoint changes within the control area have been communicated and should apply the setpoints of the control area. For example, if a control area uses four channels, when a setpoint to channel four is written all setpoints for that control area must be applied. The same mechanism is used for the verification setpoint option.

8. Modbus functions

8.1. Modbus Function Code 3 is used for reads, and Function Code 16 for writes.

8.2. The "Status Control Area n" register can be used to provide information about the status of the Lighting system. 0 indicates that everything is fine for that specific Control area. Bit 0..7 are reserved for specific use, bits 8..15 may be used by the Lighting system to indicate manufacturer-specific errors. Unresponsive luminaires should not be included in these Modus registers.

8.3. Non-consecutive Modbus registers must be readable and writable. Modbus registers associated with unused control areas must be readable and writable too.

8.4. Modbus has the option to respond to requests with exception responses, exceptions 1 to 4 should be implemented. As described at: modbus.org

9. Lighting system

9.1. When using percentages to control a Control area, a setpoint greater than 0 and lower than the minimum setpoint of a luminaire, the luminaire assumes the minimum setpoint.

9.2. When a setpoint is received at the gateway, the setpoint must be realized within 20 seconds.

9.3. After power on, the gateway must be responsive within 120 seconds.

9.4. After power on of a luminaire, it must be responsive within 180 seconds.

9.5. After power on of a luminaire and doesn't get a setpoint of the gateway the luminaire should fall back to the predefined power on setting setpoint.

9.6. The protocol describes the use up to 100 Control areas and maximum 8 Channels per Control area, these are the limits of the Protocol, the Lighting system can have lower limits.

9.7. The Automation system is expected to support controlling multiple Lighting systems gateways at the same time independently.

10. Modbus registers

10.1. There are multiple Modbus registers per Control area. All Modbus registers must be implemented and interpreted as described below.

10.2. Status Control Area n: Via these Modbus registers issues with a Control area can be communicated. A 0 means everything is okay, any other value means a fault which could result in the luminaires in the whole Control area to be turned off. Luminaires being unresponsive should not be reflected in this Modbus register.

Bit 0	General issue
Bit 1	Gateway configuration issue
Bit 2	Lighting system (wireless) network issue
Bit 3	Setpoint not realized.
Bit 4	Reserved
Bit 5	Reserved
Bit 6	Reserved
Bit 7	Reserved

Bit 8..15 can be used to indicate additional issues.

10.3. Number of luminaires Control Area n: The number of luminaires that are configured for the given Control area and should be available if the Lighting system is working properly.

10.4. Luminaires Unresponsive Control Area n: The number of luminaires that are not responding to new setpoints or otherwise not functioning as desired, either measured or calculated.

10.5. Current Power Control Area n: The actual power usage of the Control area, either measured or calculated.

10.6. Max Power Control Area n: The maximum power the Control area could draw if all Channels are at maximum and all luminaires are functioning properly.

10.7. Minimum setpoint Control Area n Channel x: The technical minimum setpoint of this Channel of this Control area in percentage. This function is not required for Module Exact Light Control.

10.8. Power on setpoint Control Area n Channel x: The setpoint for this Channel of this Control area when the luminaire is powered on and no setpoint is communicated to the Lighting system or has reached the luminaires after 180 seconds, in percentage. To set power on setting to follow the last setpoint set this value to 6553.5.

10.9. Setpoint Control Area n Channel x: The setpoint for a Channel of a Control area in percentage.

10.10. Realized Control Area n Channel x: The value of the current realized setpoint of the Lighting system of Channel of a Control area in percentage.
10.11. Setpoint in micromole Control Area n Channel x: The setpoint for a Channel of a Control area in µmol/s (or µmol/s/m^2).
10.12. Realized in µmol/s (or µmol/s/m^2)Control Area n Channel x: Value of the current setpoint of the Lighting system of Channel of a Control area in µmol/s (or µmol/s/m^2).
10.13. Verification Control Area n Channel x: A hypothetical setpoint for a Channel of a Control area in µmol/s (or µmol/s/m^2). Writing to these Modbus registers results in the relevant "Verification minimum Control Area n Channel x" and "Verification maximum Control Area n Channel x" being calculated by the Lighting system. When there is a dependency between the Channels within a Control area which results in changed maximum and minimum values for the other Channels, this Modbus register can be used to have the Lighting system calculate the maximum and minimum setpoints of the other Channels. Keep in mind that the maximum and minimum setpoint are only valid if just one parameter is changed. If more parameters must be changed a new verification has to be performed.
10.14. Verification minimum Control Area n Channel x: The minimum value a luminaire can output for the given setpoints in "Verification Control Area n Channel x" for this Channel in this Control area.
10.15. Verification maximum Control Area n Channel x: The maximum value a luminaire can output for the given setpoints in "Verification Control Area n Channel x" for this Channel in this Control area.
10.16. Verification Power Control Area n: The power the luminaries will use for the given setpoints in "Verification Control Area n Channel x" for this Control area.
10.17. Universal Input x Control Area n: With these Modbus registers additional parameters can be exchanged in the direction of the Automation system. As the content of the registers is dependent on the implementation of the Lighting System a multiplication factor must be provided in the documentation of the Lighting System gateway.
10.18. Universal Output x Control Area n: With these Modbus registers additional parameters can be exchanged in the direction of the Lighting system. As the content of the registers is dependent on the implementation of the Lighting System a multiplication factor must be provided in the documentation of the Lighting System gateway.
10.19. Preferred Setpoint Channel n Control Area x: The setpoints preferred by the Lighting system in µmol/s (or µmol/s/m^2) or %. The automation system can read these setpoints and write them as setpoint to be activated using the base setpoint

or using the module exact light control moment it wants to activate that set of setpoints.

10.20. Select Spectral Composition Preset Control Area x: The spectral composition, preset or scenario to be selected by the Automation System. The selection results in the corresponding set of preferred setpoints to be made available by the Lighting system. The same number, offset by 10000, would result in the spectral composition to be activated directly.

10.21. Spectral Composition Preset Dimming Percentage Control Area x: Percentage of the Spectral Composition to be returned via the Preferred Setpoint Channel n Control Area x registers or to be applied if set directly via Select Spectral Composition Preset Control Area x.

General Settings

Register (Offset)	Parameter name	Data-type	Multiplier	R/W	Range
0	Serial Number first half	U16	1	Read	0..65535
1	Serial Number second half	U16	1	Read	0..65535
2	Product model	U16	1	Read	0..65535
3	Firmware version number Major	U16	1	Read	0..65535
4	Firmware version number Minor	U16	1	Read	0..65535
5	Firmware version number Patch	U16	1	Read	0..65535
6	Hardware version number Major	U16	1	Read	0..65535
7	Hardware version number Minor	U16	1	Read	0..65535
8	Hardware version number Patch	U16	1	Read	0..65535
9	Protocol version Major	U16	1	Read	0..65535
10	Protocol version Minor	U16	1	Read	0..65535
11	Protocol version Patch	U16	1	Read	0..65535
12	Supported Modules	U16	1	Read	Bit 0; System Status; 0=no/1=yes Bit 1; Power; 0=no/1=yes Bit 2; Exact Licht Control; 0=no/1=yes Bit 3; Universal Inputs; 0=no/1=yes

					Bit 4; Universal Outputs; 0=no/1=yes Bit 5; Preferred setpoints; 0=no/1=yes Bit 6..15; Reserved
13	Reserved				
14	Reserved				
15	Reserved				
16	Reserved				
17	Reserved				
18	Reserved				
19	Reserved				
20	Node address	U16	1	R/W	1..247, 1 is default
21	Baud rate	U16	0,01 (value should be divided by 100, f.i. 12=1200:)	R/W	1200, 2400, 4800, 9600, default 19200, 38400, 57600, 115200
22	Data bits	U16	1	R/W	1=7/2=8, 2=8 is default
23	Parity	U16	1	R/W	1=N/2=E/3=O, 2=E is default
24	Stop bit	U16	1	R/W	1=1/2=1.5/3=2, 1=1 is default
25	Reserved				
26	Reserved				
27	Reserved				
28	Reserved				
29	Reserved				
30	IP address first octet	U16	1	R/W	0..255, 192 is default

31	IP address second octet	U16	1	R/W	0..255, 168 is default
32	IP address third octet	U16	1	R/W	0..255, 0 is default
33	IP address fourth octet	U16	1	R/W	1..254, 100 is default
34	Reserved				
35	Netmask first octet	U16	1	R/W	0..255, 255 is default
36	Netmask second octet	U16	1	R/W	0..255, 255 is default
37	Netmask third octet	U16	1	R/W	0..255, 255 is default
38	Netmask fourth octet	U16	1	R/W	0..255, 0 is default
39	Reserved				
40	Gateway first octet	U16	1	R/W	0..255, 192 is default
41	Gateway second octet	U16	1	R/W	0..255, 168 is default
42	Gateway third octet	U16	1	R/W	0..255, 0 is default
43	Gateway fourth octet	U16	1	R/W	1..254, 1 is default
44	Reserved				
45	Appy settings	U16	1	R/W	0..65535, > 0 apply settings. The value returns to 0 after successful application of the settings.
46	Reserved				
47	Reserved				
48	Reserved				
49	Reserved				

						Module						
Register (Offset)	**Parameter name**	**Data type**	**Multi -plier**	**R/W**	**Range**	**Base**	**(I)**	**(II)**	**(III)**	**(IV)**	**(V)**	**(VI)**
100	Status Control Area 1	U16	1	Read	0..65535		x					
200	Number of luminaires Control Area 1	U16	1	Read	0..65535		x					
300	Luminaires Unresponsive Control Area 1	U16	1	Read	0..65535		x					
400	Current Power Control Area 1	U16	10	Read	0.0..6553.5kW			x				
500	Max Power Control Area 1	U16	10	Read	0.0..6553.5kW			x				
600	Minimum setpoint Control Area 1 Channel 1	U16	10	Read	0.0..100.0%		x					
700	Minimum setpoint Control Area 1 Channel 2	U16	10	Read	0.0..100.0%		x					
800	Minimum setpoint Control Area 1 Channel 3	U16	10	Read	0.0..100.0%		x					
900	Minimum setpoint Control Area 1 Channel 4	U16	10	Read	0.0..100.0%		x					
1000	Minimum setpoint Control Area 1 Channel 5	U16	10	Read	0.0..100.0%		x					
1100	Minimum setpoint Control Area 1 Channel 6	U16	10	Read	0.0..100.0%		x					
1200	Minimum setpoint Control Area 1 Channel 7	U16	10	Read	0.0..100.0%		x					
1300	Minimum setpoint Control Area 1 Channel 8	U16	10	Read	0.0..100.0%		x					
1400	Power on setpoint Control Area 1 Channel 1	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
1500	Power on setpoint Control Area 1 Channel 2	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
1600	Power on setpoint Control Area 1 Channel 3	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
1700	Power on setpoint Control Area 1 Channel 4	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
1800	Power on setpoint Control Area 1 Channel 5	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				

1900	Power on setpoint Control Area 1 Channel 6	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
2000	Power on setpoint Control Area 1 Channel 7	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
2100	Power on setpoint Control Area 1 Channel 8	U16	10	R/W	0.0..100.0% 6553.5=last setpoint			x				
2200	Setpoint Control Area 1 Channel 1	U16	10	R/W	0.0..100.0%	x						
2300	Setpoint Control Area 1 Channel 2	U16	10	R/W	0.0..100.0%	x						
2400	Setpoint Control Area 1 Channel 3	U16	10	R/W	0.0..100.0%	x						
2500	Setpoint Control Area 1 Channel 4	U16	10	R/W	0.0..100.0%	x						
2600	Setpoint Control Area 1 Channel 5	U16	10	R/W	0.0..100.0%	x						
2700	Setpoint Control Area 1 Channel 6	U16	10	R/W	0.0..100.0%	x						
2800	Setpoint Control Area 1 Channel 7	U16	10	R/W	0.0..100.0%	x						
2900	Setpoint Control Area 1 Channel 8	U16	10	R/W	0.0..100.0%	x						
3000	Realized Control Area 1 Channel 1	U16	10	Read	0.0..100.0%		x					
3100	Realized Control Area 1 Channel 2	U16	10	Read	0.0..100.0%		x					
3200	Realized Control Area 1 Channel 3	U16	10	Read	0.0..100.0%		x					
3300	Realized Control Area 1 Channel 4	U16	10	Read	0.0..100.0%		x					
3400	Realized Control Area 1 Channel 5	U16	10	Read	0.0..100.0%		x					
3500	Realized Control Area 1 Channel 6	U16	10	Read	0.0..100.0%		x					
3600	Realized Control Area 1 Channel 7	U16	10	Read	0.0..100.0%		x					
3700	Realized Control Area 1 Channel 8	U16	10	Read	0.0..100.0%		x					
3800	Universal Input 1 Control Area 1	S16		Read	0..65535					x		
3900	Universal Input 2 Control Area 1	S16		Read	0..65535					x		
4000	Universal Input 3 Control Area 1	S16		Read	0..65535					x		

4100	Universal Input 4 Control Area 1	S16		Read	0..65535					x		
4200	Universal Input 5 Control Area 1	S16		Read	0..65535					x		
4300	Universal Input 6 Control Area 1	S16		Read	0..65535					x		
4400	Universal Input 7 Control Area 1	S16		Read	0..65535					x		
4500	Universal Input 8 Control Area 1	S16		Read	0..65535					x		
4600	Universal Input 9 Control Area 1	S16		Read	0..65535					x		
4700	Universal Input 10 Control Area 1	S16		Read	0..65535					x		
4800	Verification Power Control Area 1	U16	10	Read	0.0..6553.5kW			x				
5000	Setpoint in micromole Control Area 1 Channel 1	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5100	Setpoint in micromole Control Area 1 Channel 2	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5200	Setpoint in micromole Control Area 1 Channel 3	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5300	Setpoint in micromole Control Area 1 Channel 4	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5400	Setpoint in micromole Control Area 1 Channel 5	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5500	Setpoint in micromole Control Area 1 Channel 6	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5600	Setpoint in micromole Control Area 1 Channel 7	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5700	Setpoint in micromole Control Area 1 Channel 8	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
5800	Realized in micromole Control Area 1 Channel 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
5900	Realized in micromole Control Area 1 Channel 2	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			

6000	Realized in micromole Control Area 1 Channel 3	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6100	Realized in micromole Control Area 1 Channel 4	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6200	Realized in micromole Control Area 1 Channel 5	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6300	Realized in micromole Control Area 1 Channel 6	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6400	Realized in micromole Control Area 1 Channel 7	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6500	Realized in micromole Control Area 1 Channel 8	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
6600	Verification Control Area 1 Channel 1	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
6700	Verification Control Area 1 Channel 2	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
6800	Verification Control Area 1 Channel 3	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
6900	Verification Control Area 1 Channel 4	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
7000	Verification Control Area 1 Channel 5	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
7100	Verification Control Area 1 Channel 6	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
7200	Verification Control Area 1 Channel 7	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
7300	Verification Control Area 1 Channel 8	U16	10	R/W	0.0..6553.5 µmol/s/m² or µmol/s				x			
7400	Verification minimum Control Area 1 Channel 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
7500	Verification minimum Control Area 1 Channel 2	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			

7600	Verification minimum Control Area 1 Channel 3	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
7700	Verification minimum Control Area 1 Channel 4	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
7800	Verification minimum Control Area 1 Channel 5	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
7900	Verification minimum Control Area 1 Channel 6	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8000	Verification minimum Control Area 1 Channel 7	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8100	Verification minimum Control Area 1 Channel 8	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8200	Verification maximum Control Area 1 Channel 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8300	Verification maximum Control Area 1 Channel 2	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8400	Verification maximum Control Area 1 Channel 3	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8500	Verification maximum Control Area 1 Channel 4	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8600	Verification maximum Control Area 1 Channel 5	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8700	Verification maximum Control Area 1 Channel 6	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8800	Verification maximum Control Area 1 Channel 7	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
8900	Verification maximum Control Area 1 Channel 8	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s				x			
9000	Universal Output 1 Control Area 1	S16		R/W	0..65535						x	
9100	Universal Output 2 Control Area 1	S16		R/W	0..65535						x	

9200	Universal Output 3 Control Area 1	S16		R/W	0..65535						x	
9300	Universal Output 4 Control Area 1	S16		R/W	0..65535						x	
9400	Universal Output 5 Control Area 1	S16		R/W	0..65535						x	
9500	Universal Output 6 Control Area 1	S16		R/W	0..65535						x	
9600	Universal Output 7 Control Area 1	S16		R/W	0..65535						x	
9700	Universal Output 8 Control Area 1	S16		R/W	0..65535						x	
9800	Universal Output 9 Control Area 1	S16		R/W	0..65535						x	
9900	Universal Output 10 Control Area 1	S16		R/W	0..65535						x	
10000	Preferred Setpoint Channel 1 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10100	Preferred Setpoint Channel 2 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10200	Preferred Setpoint Channel 3 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10300	Preferred Setpoint Channel 4 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10400	Preferred Setpoint Channel 5 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10500	Preferred Setpoint Channel 6 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10600	Preferred Setpoint Channel 7 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10700	Preferred Setpoint Channel 8 Control Area 1	U16	10	Read	0.0..6553.5 µmol/s/m² or µmol/s							x
10800	Select Spectral Composition Preset Control Area 1	U16	1	R/W	0..65535							x

10900	Spectral Composition Preset Dimming Percentage Control Area 1	U16	10	R/W	0.0..100.0%							x

Parameters

All parameters in this table are available for all 100 possible control areas, only the first registers for control area 1 are listed.

Appendix A: Horti Lighting Protocol Version Comparison Analysis

Comparison between Version 1.0.3 (March 2024) and Version 1.1.0 (May 2025)

1. Key Changes Overview

The transition from Version 1.0.3 to Version 1.1.0 brings several significant modifications and enhancements to the Horti Lighting Protocol:

1. **Simplified Verification Mechanism**: The ELC (Exact Light Control) module verification process has been simplified to focus on essential functionality
2. **Module Renaming**: "Universal Measurements" module renamed to "Universal Inputs" for clarity
3. **New Module Addition**: Added "Universal Outputs" module (Module V)
4. **New Module Addition**: Added "Preferred Setpoints" module (Module VI)
5. **Register Range and Functionality Expansion**: Extended functionality through additional modules and registers
6. **Security Clarification**: Explicitly stated that security is outside HLP scope while providing basic network separation guidance

The following sections provide detailed analysis of each major change area, explaining both the technical modifications and their practical implications for implementers.

2. Detailed Modifications

This section examines the specific changes between protocol versions, highlighting differences in module structure, verification processes, register allocation, and security considerations.

2.1 Module Changes

The module structure has been expanded and clarified in Version 1.1.0 to provide greater functionality while maintaining backward compatibility with existing implementations. The table below summarizes the module changes between versions:

Module	Version 1.0.3	Version 1.1.0
I. System Status	Included	Unchanged - Provides system status feedback
II. Power	Included	Unchanged - Provides power usage feedback
III. Exact Light Control	Included	Simplified verification mechanism
IV. Universal Inputs	Universal Measurements	Renamed for clarity
V. Universal Outputs	Not present	New bidirectional parameter exchange
VI. Preferred Setpoints	Not present	Enables lighting system spectral composition specification

The addition of two new modules represents a significant enhancement in protocol capabilities, particularly in terms of bidirectional communication and lighting system autonomy.

2.2 ELC Module Verification Process

The verification process in Version 1.1.0 has been fundamentally simplified compared to Version 1.0.3, focusing on providing an essential algorithm that works reliably with minimal complexity:

Version 1.0.3 Process: - Required setting all setpoints to zero at start - Multi-step process with successive verification of each channel - Complex workflow with detailed sequence requirements

Version 1.1.0 Process: - Streamlined approach focused on the essential steps needed for verification - Basic algorithm that works with minimal implementation requirements - Additional data (min/max values, power estimates) available but optional for optimization - More flexibility in implementation while maintaining protocol compatibility

The revised approach provides a straightforward baseline verification mechanism that will work in all scenarios, while allowing implementers to optimize their applications using the additional verification data if desired. This makes the protocol more accessible to implementers while simultaneously offering pathways for advanced optimization.

2.3 Status Reporting

Version 1.1.0 adds a new status bit (Bit 3: “Setpoint not realized”) to the Status Control Area register, enhancing error reporting capabilities.

2.4 Register Allocation and Type Changes

Feature	Version 1.0.3	Version 1.1.0
Modbus registers	0…8999	0…10899
Reserved for future expansion	9000…31999	10900…31999
Universal Inputs	3800-4799 (U16)	3800-4799 (S16)
Universal Outputs	Not present	9000-9999 (S16)
Preferred Setpoints	Not present	10000-10899

Register Type Changes: - Universal Inputs (formerly Universal Measurements) changed from unsigned (U16) to signed (S16) integer types - Universal Outputs implemented as signed (S16) integer types - This change allows for negative values in measurements and control signals, expanding the range of possible applications (e.g., relative measurements, bidirectional controls).

2.5 Security Clarifications

Version 1.1.0 clarifies that security is outside the scope of the HLP protocol while providing basic guidance: - Explicitly states that the protocol does not prescribe security regulations -

Recommends network separation as a simple security measure (no internet connection for the network between automation system and lighting gateway) - Emphasizes that when networks are kept separate, elaborate security measures become less critical

2.6 Local Gateway Access

Version 1.0.3 only required: - “Reset the Modbus and IP settings back to default”

Version 1.1.0 expands this requirement: - “Reset the Modbus and IP settings back to default and/or a method to approach the gateway locally at all times”

This change ensures that gateway devices remain accessible for configuration and troubleshooting purposes even if network settings are misconfigured. Local access capability provides a reliable fallback method when remote access is compromised or unavailable.

3. Module Details

The modifications to existing modules and addition of new modules represent a significant expansion of the protocol’s capabilities. This section provides more detailed information on the key module changes.

3.1 New Module: Universal Outputs

Module V (“Universal Outputs”) provides: - Up to ten free-to-use outputs (from the perspective of the automation system) per control area - Allows more flexible parameter exchange in the direction of the lighting system - Uses Modbus registers 9000-9999

3.2 New Module: Preferred Setpoints

Module VI (“Preferred Setpoints”) provides: - Option for lighting system to communicate preferred spectral composition - Automation system can select a preset/scenario and optional dimming percentage - Can be used on top of basic implementation or Module III (Exact Light Control) - Uses Modbus registers 10000-10899

3.3 Module “Universal Measurements” to “Universal Inputs”

- Functionality remains similar but renamed for clarity
- Better reflects the directional nature of the data flow (inputs to the automation system)

4. Terminology Updates

The new version introduces some terminology changes to improve clarity and better reflect the protocol’s evolving focus. These terminology updates help align the language with the protocol’s conceptual model.

Version 1.1.0 adds new terminology to the glossary: - “Spectral composition”: Sometimes referred to as recipe, set of setpoints for multiple channels or colors without a definition of time - Replaces some instances of “light recipe” with “spectral composition”

5. Impact Assessment

The changes in Version 1.1.0 have various implications for existing and new implementations. This section evaluates the practical impact of these changes from both compatibility and implementation perspectives.

5.1 Backward Compatibility

The protocol maintains backward compatibility in core functionality: - Basic protocol structure remains the same - Original four modules retain their core functionality - Register allocations for existing functionality are unchanged

5.2 Implementation Considerations

Implementers upgrading from Version 1.0.3 to Version 1.1.0 should: 1. Update verification process implementation if using Module III 2. Update status bit interpretation to handle new “Setpoint not realized” bit 3. Consider implementing new modules if beneficial for their application 4. Update security measures according to new recommendations

6. Conclusion

Version 1.1.0 represents a significant enhancement to the Horti Lighting Protocol with simplifications to existing functionality and extensions to meet more advanced control needs. The simplified verification mechanism reduces implementation complexity, while the new modules provide greater flexibility for system integration and control.