Technical Manual

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Prepared by:	Pieter Fourie Keegan Titus Michael Rust	*Signature:*
Checked by:		*Signature:*
Approved by:		*Signature:*

VERSION HISTORY

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ACRONYMS AND ABBREVIATIONS

NRF	National Research Foundation
SAAO	South African Astronomical Observatory
SOP	Standard Operating Procedure

DEFINITIONS

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1. Introduction

The PLC based roof controller assists in the control of the Super Wasp Telescope roof by adding some additional control to ensure the roof is properly controlled under a variety of conditions.

The controller can work in conjunction with the existing roof control and augment the functions of the existing roof controller.

The PLC based controller can also operate independently from the existing roof controller and commands are then issued to the controller via an RS-232 port. The communications protocol is described in Appendix A, PC commands are listed under sections 3.2 and 3.3

2. Block Diagram

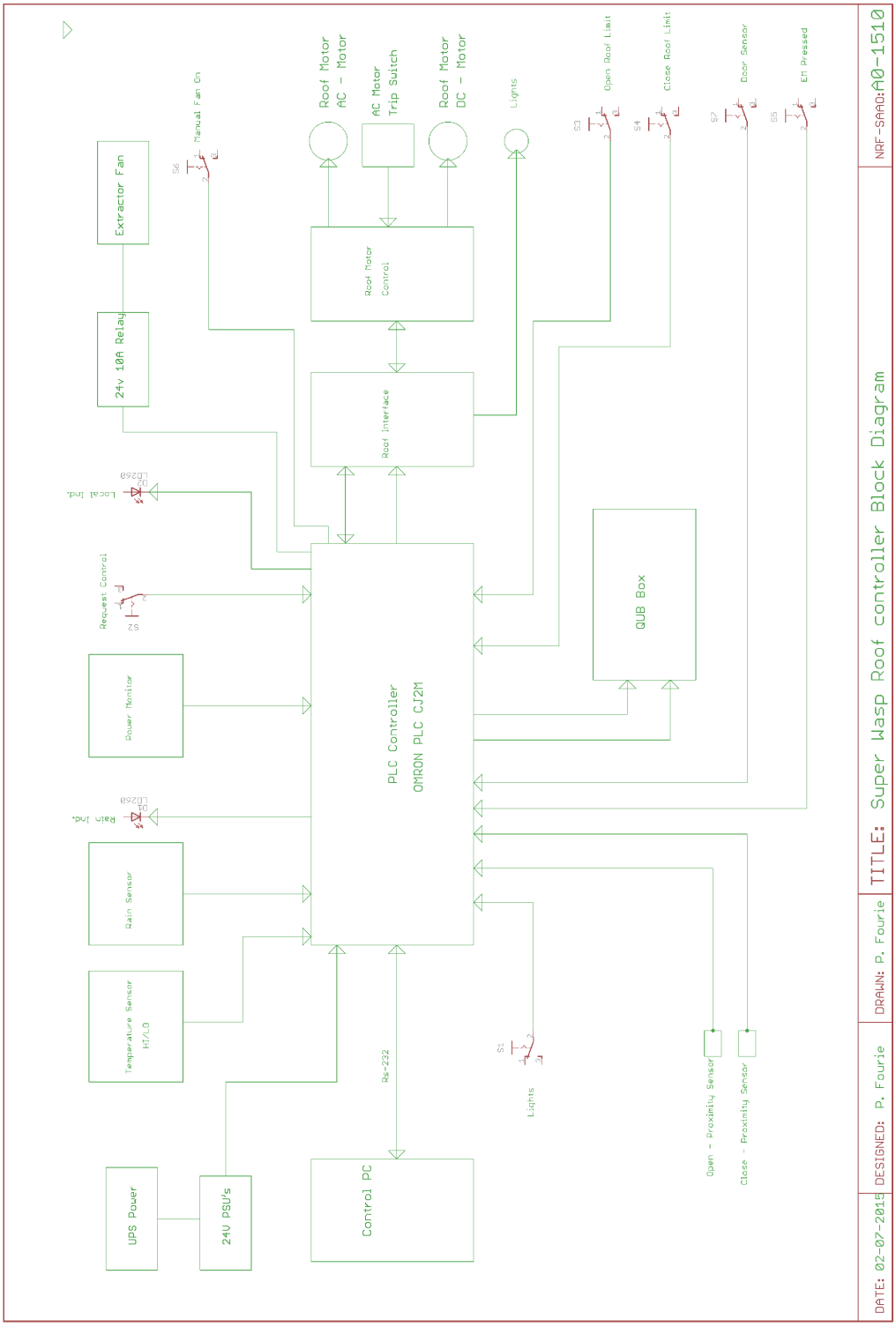


Figure 1: Block diagram of PLC-based Roof Control system

2.1 System description

The PLC controller accept several signals from different devices and make decisions regarding the opening and closing of the roof depending on the status of the input signals.

Devices that supply input and output signals:

- *Control PC* – This is the primary device from which commands can be issued or status regarding the roof can be requested.
- *Cloud detector* – The cloud detector supplies a signal that is used by the PLC controller to determine the weather conditions. This signal can trigger closures or prevent the roof from opening.
- *Power Monitor* – The power monitor signal is a signal that indicates the status of the incoming mains. This signal is used to close the roof if the power remains off for a predetermined period.
- *Roof limits* – The roof limits indicate if the roof is open or closed. Proximity sensors have been added as a fail safe if the limit switches fail.
- *Roof Interface* – The roof interface converts the signals from the PLC controller to the required signals that control the actual roof motors.
- *QUB Box* – The QUB no longer has any control over the roof but it does receive the status of the li,its from the PLC.
- *Temperature sensor* – The temperature sensor monitors the control room temperature.
- *Extractor Fan* – The extractor fan will be switched on if the temperature inside the control room goes above a preset limit.
- *Lights* – This function is a future improvement that will not be implemented during this upgrade.

3. Detailed description of the PLC Controller

The PLC Controller is based on the OMRON CJ2M Mini PLC. The plc has 32 inputs and 32 Outputs and a RS-232 port. The PLC ports can be expanded if required.

All the input signals are open collector or switches and the signals must be in the range 0v to 24V.

All the output signals are Open Collector transistor common Emitter (NPN) signals in the range 0 - 24V.

The system voltage for this application is 24V.

3.1 Control PC

The control PC is the primary device from where commands to the PLC are issued. The control PC commands are summarised in the Excel file 'Super WASP – PLC Command Structure'.

The communication between the Control PC and the PLC is based on the Omron Host-link protocol. This is explained in a separate document. Communicating with the CJ2M PLC.

The control PC can only issue one command string. This string contains all the information that can be passed on to the PLC. Several commands can be issued simultaneously without affecting the operations. The PLC will reply with an acknowledge string.

The Control PC can request status from the PLC at any time. There is no time constraint when a command can be issued and when status can be requested. The PLC will return a string with all the status information regarding the system.

This mode of operation simplifies the software in the control PC since only one command string and one status string has to be manipulated.

3.2 Commands from Control PC

Please note that the commands below will only be executed by the PLC if the system is under remote control.

Function	PLC bit address	Description
*Close Roof	100.0	The Control PC will set this bit to issue a 'Close Roof' Command.
*Open Roof	100.1	The control PC will set this bit to issue an 'Open Roof' Command

**Once an Open/Close command is issued, there is a delay of four seconds to allow the motor to run up to speed.*

The Close Roof and Open Roof commands from the Control PC will only be executed when the following conditions are met.

1. *The Roof interface is set to Remote.*
2. *The Motor Stop is not pressed.*
3. *The Rain Sensor is not triggered.*
4. *There is no power failure.*

If the above conditions are met the roof can be opened or closed from the Control PC. The opening or closing of the roof will take place as long as the command is issued. Example. If the command is issued to close the roof and the bit is reset while the roof is closing the motors will stop at that point. This will allow the user to open and close the roof only fractionally.

Table 1: Commands from Control PC

Function	PLC bit address	Description
Mains/Battery motor	100.2	Setting this bit will select the Mains motor as the control motor. If the bit is reset the DC motor is used. This bit is ignored if the system is under Manual control.
Rain Sensor On/Off	100.4	Setting this bit enables the rain sensor. If this bit is not set when it is raining the roof will not close automatically
Request roof control	100.8	The bit is momentarily set to request remote control. Setting the bit from 0 to 1 will set remote operation. It is important that this bit is reset to 0 once control is established.
Accept power delay	100.12	Setting this bit briefly to inform the PLC that the delay before Power Failure closure must be accepted.
Accept Communications delay	100.13	Setting this bit briefly informs the PLC that the delay before closure due to communications failure must be accepted.
Watchdog Reset	100.15	This bit must be set with each command that is issued. The PLC will check the time between commands if the control is set to Remote Control. The Control PC must send a command string at least once within the communications delay period. If the Control PC does not send a command within this period the PLC will assume the PC has crashed and closure of the roof will take place.

Table 1: Commands from Control PC

Function	PLC bit address	Description
Delay after Power Failure Closure	101	This is a BCD number between 0 and 9999. The value is the number of seconds that the power must be off before the roof will start to close. This has been incorporated to ensure that the roof will close when the power has failed and communications with the system has failed due to the power failure. Regardless of the mode of control the Open/Close commands are ignored and the roof is closed. The time after a failure must be set to such a value that the closure will not take place before the generator takes control and it must be short enough so that the UPS will not run out before the closure. The closure will take place using the battery driven motor. The best time is about 180 seconds.
Delay before Communications failure closure	102	This is a BCD number between 0 and 9999. The value is the number of seconds that must elapse after a command was issued before the PLC will close the dome assuming a communications failure. A typical time is about 600 seconds. This timer is ignored if the control is set to manual control.

Table 1: Commands from Control PC

3.3 Status to the Control PC

The Control PC can request Status from the PLC and the PLC will return a string with all the status bits. The Control PC can request status regardless of the mode of control that is selected.

Function	PLC bit address	Description
Roof Closed	150.0	This bit is set if the roof is completely closed. *Cross reference PLC bit 150.11.*
Roof Open	150.1	This bit is set if the roof is completely open. *Cross reference PLC bit 150.14.*
Roof Moving	150.2	This bit is set while a roof motor is switched on. The bit will be set if the roof is moving.
Roof Remote/Manual	150.3	This bit is set when under remote control.
Raining	150.4	This bit is set if the rain sensor is detecting rain. When this bit is set and the control bit has enabled the sensor the roof will be closed.
Forced Rain Closure	150.5	This bit is set to indicate that the roof is closed due to rain and that no control is possible.
Building temp high	150.6	This bit is set if the temperature inside the control room exceeds a preset hardware limit. The hardware limit can be adjusted by a technician.
Extractor fan ON	150.7	This bit is set if the, newly installed, extractor fan in the control room is on. The extractor fan is switched on automatically if the building temp is high or it can be switched on manually with a switch located on the PLC cabinet.
Motor Stop Pressed	150.8	This bit is set when the motor stop is pressed. While this bit is set the roof can not be moved. If this bit is set at the beginning of the observing night please contact the duty technician to release the button.

Table 2: Status to Control PC

Function	PLC bit address	Description
Roof AC motor status	150.9	If this bit is set the AC motor has tripped.
Roof motor in use	150.10	If this bit is set the battery motor is in use. If this bit is not set the AC motor is in use.
Close proximity	150.11	If this bit is set the closed proximity sensor has been tripped. This means the roof is closed. *Cross reference PLC bit 150.0.*
Power Failure	150.12	This bit is set when the power has failed. The roof will be closed if the power does not return in the period set in the 'Delay after Power Failure Closure.
Forced Power closure	150.13	This bit is set if the roof is closed because the power failure is longer than the Delay after power failure closure.
Open proximity	150.14	This bit is set if the open proximity sensor is tripped. This means that the roof is open. *Cross reference PLC bit 150.1.*
Door sensor	150.15	This bit is set if the door between the telescope and the control room is open.

Table 2: Status to Control PC

4. QUB Box

The control can no longer take place via the QUB box.

In the new system the PLC will be returning the status of the roof to the QUB but there will be no further interaction. As a result of this the QUB no longer has any control over the roof.

5. Cloud Detector

The raining signal is derived from the cloud detector that is already in the Super Wasp system. The PLC will close the roof if the detector detects rain and the signal is enabled.

6. UPS

The *power - failed* signal is derived from the incoming mains and the PLC will close the roof if the power remains off for longer than the set period. It is important that the delay period is not too long or the power to the PLC will fail if the UPS shuts down and the roof cannot be closed then.

7. Remote / Manual control

In the new system control can be requested by the user (Remote or Local operator). The PLC will grant control to the last user that requests it. Note that the PLC recognizes a request for control by looking at the transition of the bit from 0 to 1. Keeping the bit set to 1 will not guarantee retention of control.

Appendix A: Communication with the CJ2M PLC

There are two modes in which a computer can be used to communicate with the CJ2M PLC.

- Using the CX-Programmer program. This mode is used when the program in the PLC must be changed or faultfinding using the CX-Programmer online monitoring functions. This mode is only to be used by a person who is familiar with the system since fatal changes can be made and a loss of the program and system settings can result
- Host link communication. The program that will request the PLC to perform certain functions in normal use will use this mode of communication. The PLC must be in monitor mode to ensure that data can be written to the PLC from the host computer.

PLC Switch settings for selecting a required communications mode.

Memory settings

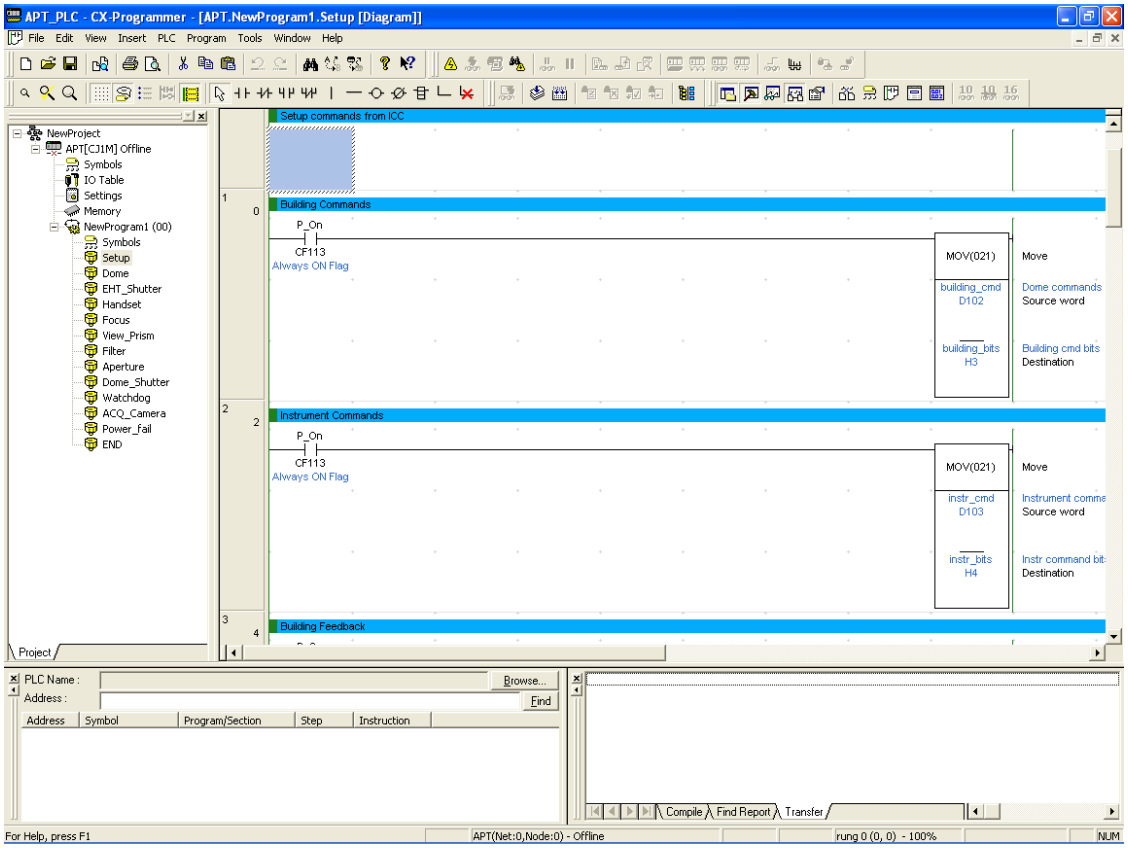
The communication parameters (speed, number of bits, parity and stop bits) are all written into certain memory locations. If these parameters are lost the CX-programmer must be used to correct them for proper operation of the PLC.

The mode the PLC is operating in is also preset to Monitor mode. If this mode is different the host computer will not be able to write instructions to the PLC. This can be changed from the host computer without using the CX-programmer. The CX-programmer will be required if the changes must be made permanent.

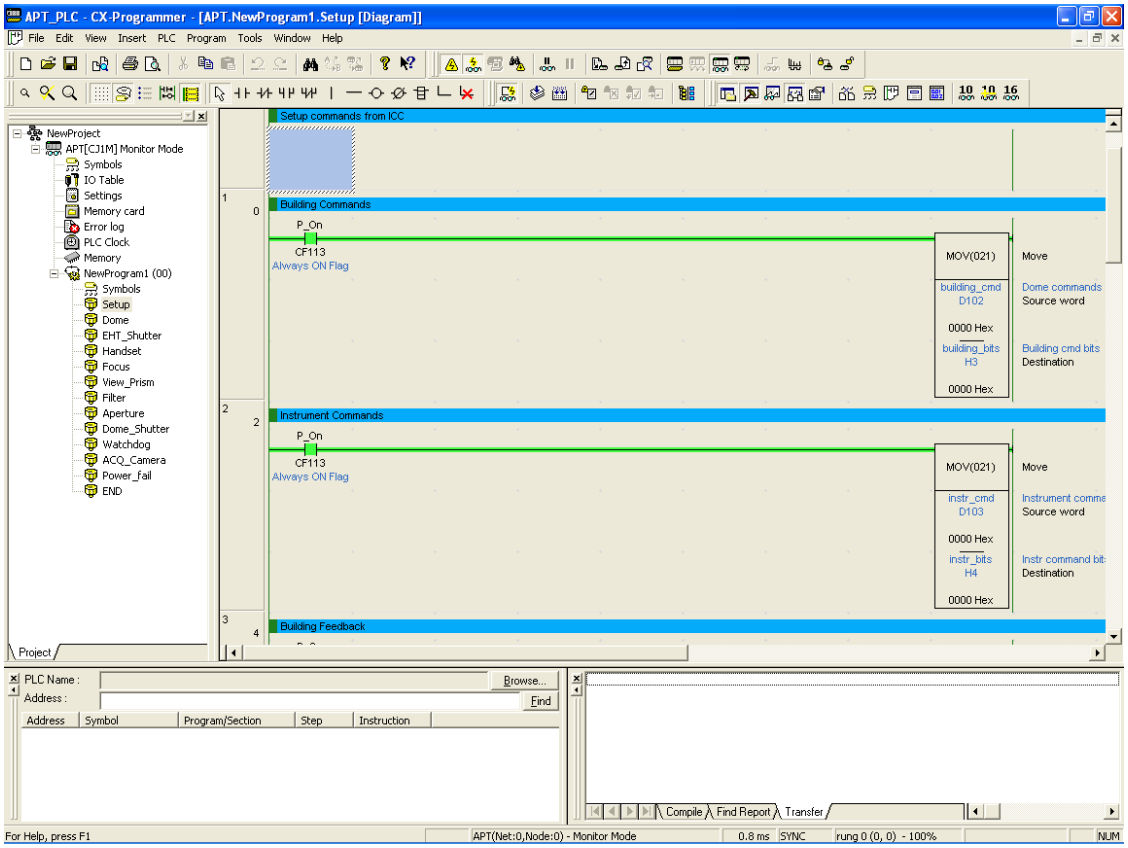
The following table will summarize the memory locations that can affect the operation of the PLC and how they can be changed.

Steps that must be followed to change these locations

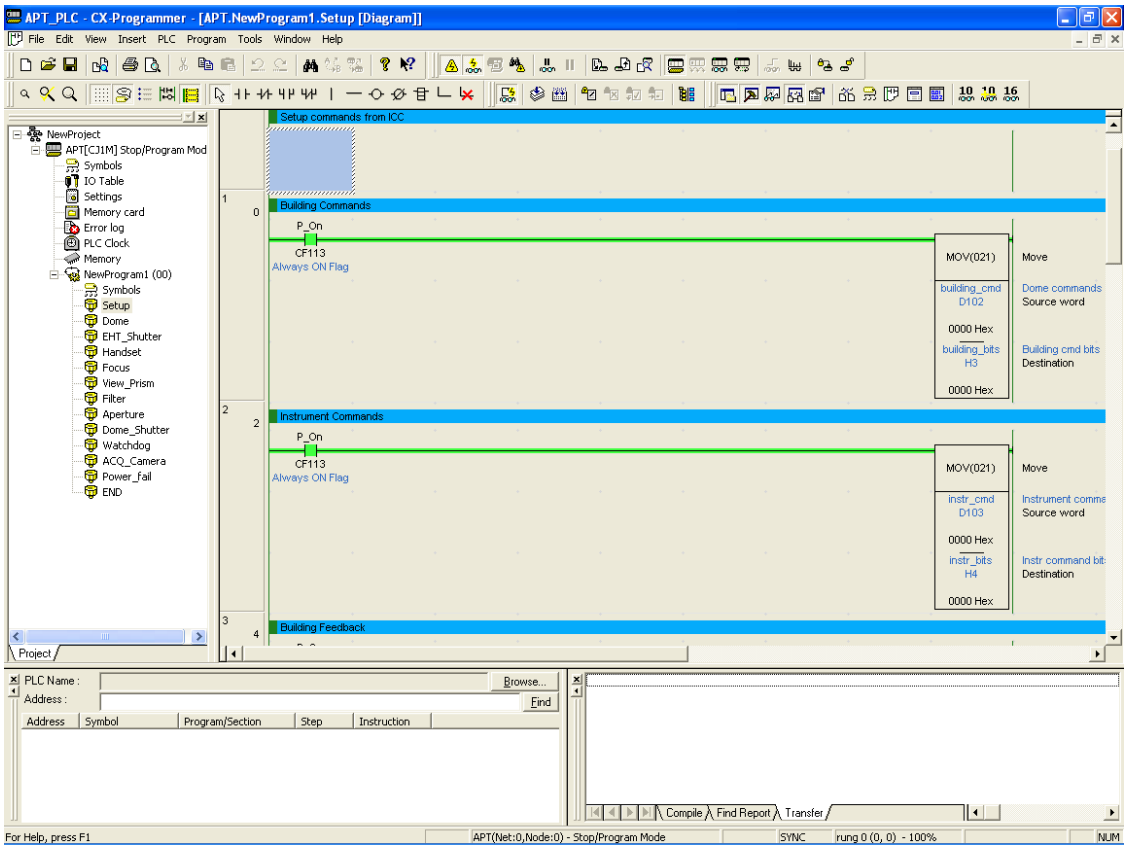
- Start CX programmer program on computer and load the ladder program for the PLC.



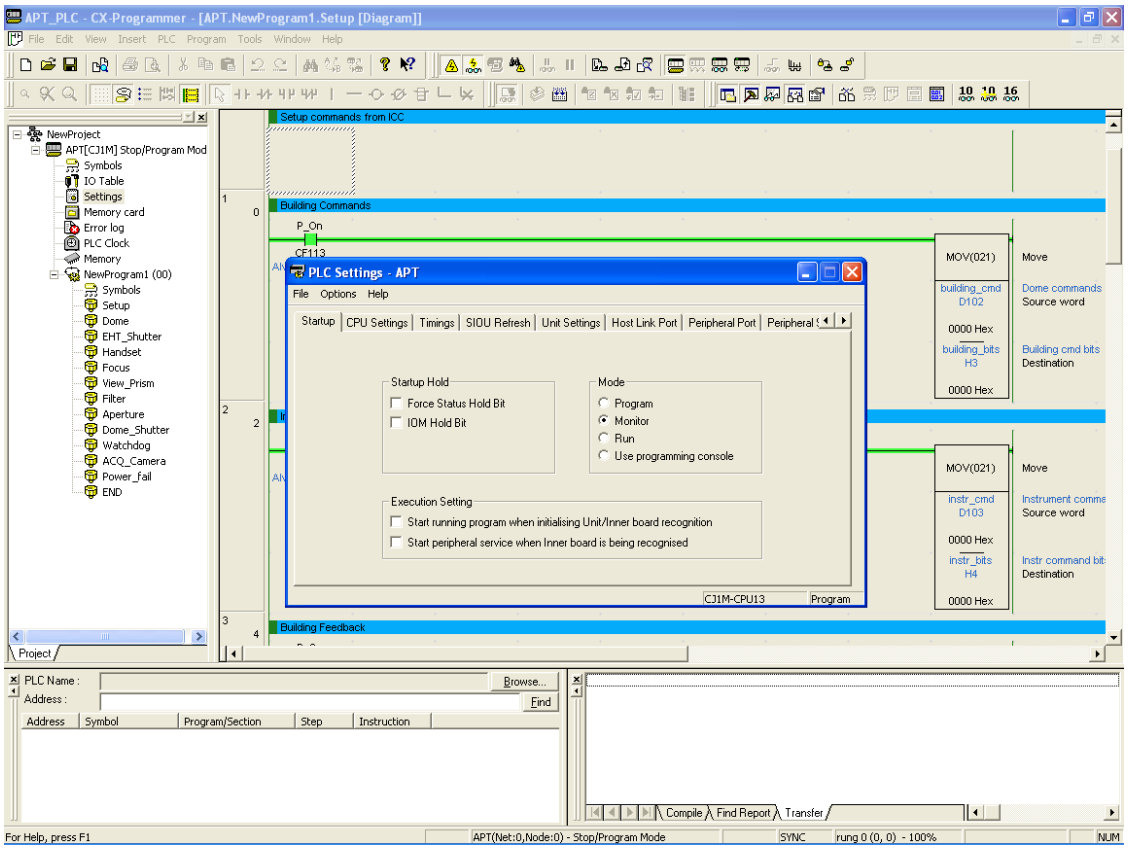
- Connect to the PLC



- Switch the PLC to program mode

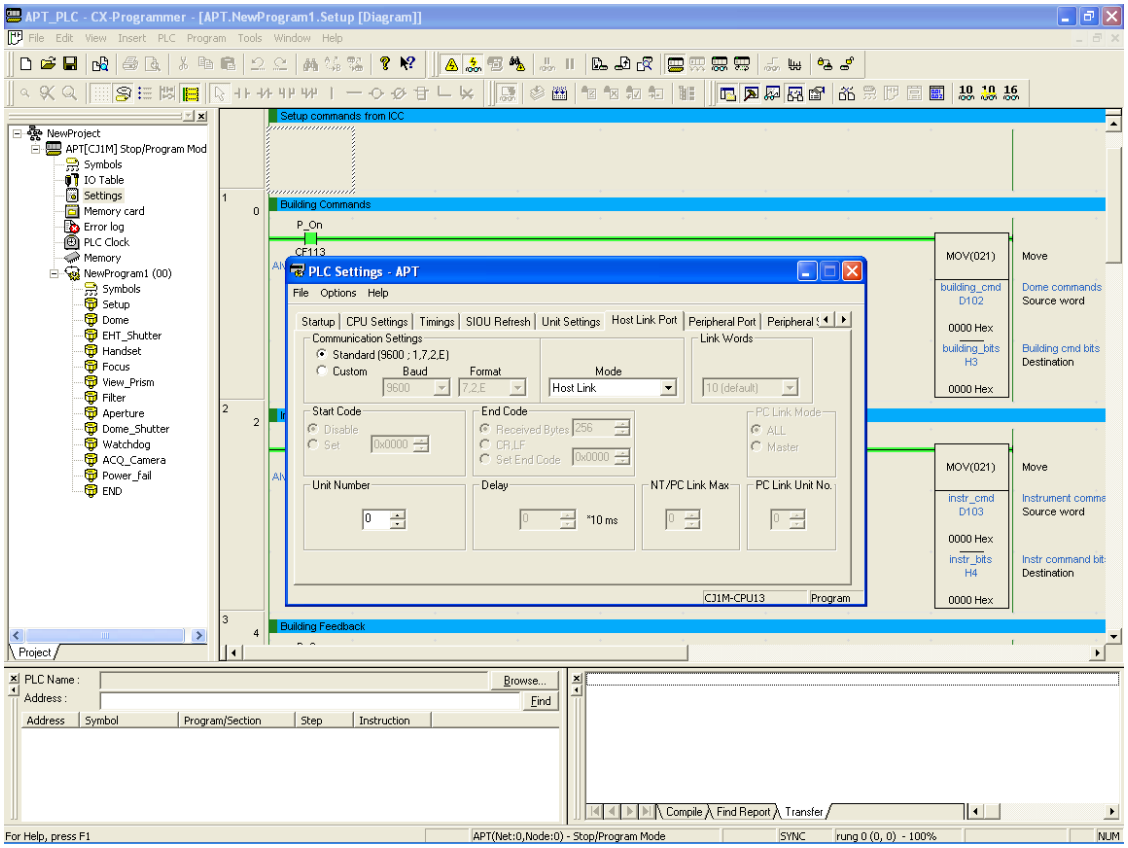


- Select the ‘Settings’ functions.



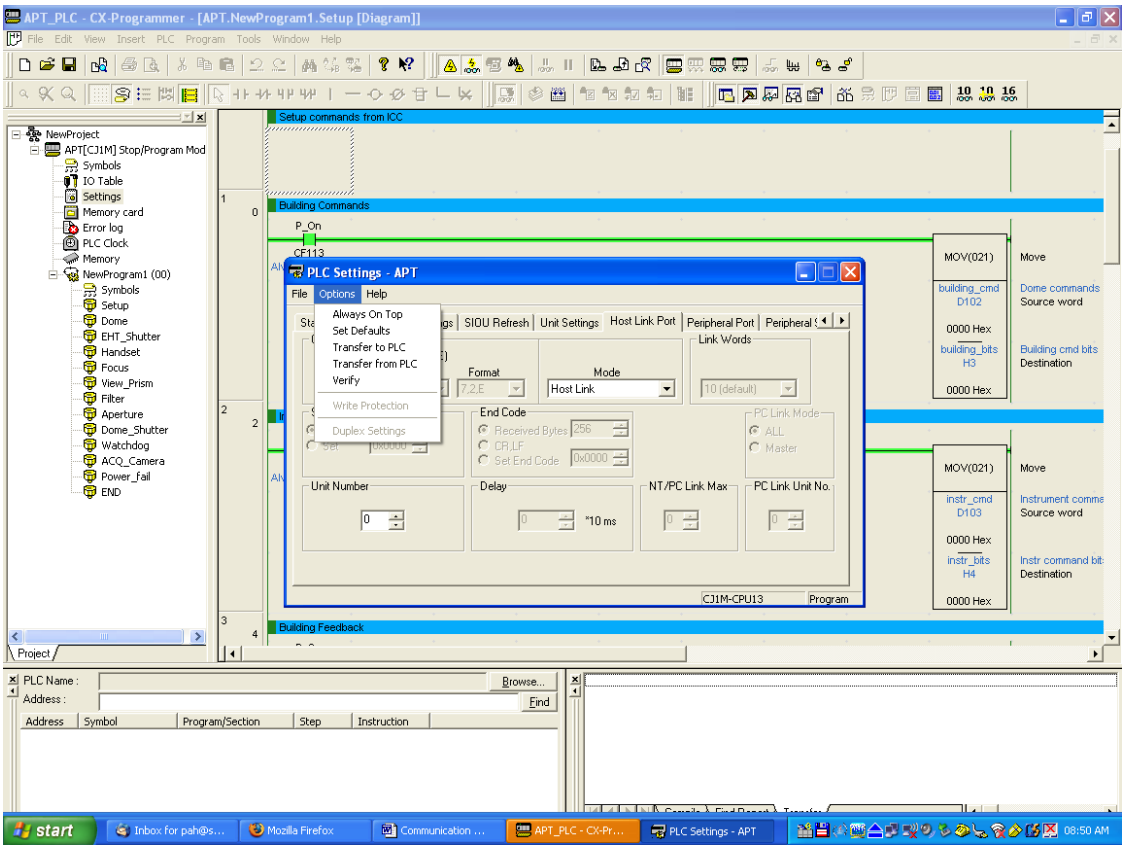
Make sure the ‘Monitor’ Mode is selected.

- Select ‘Host Link Port’



Select ‘Standard’ and ‘Host Link’ Mode.

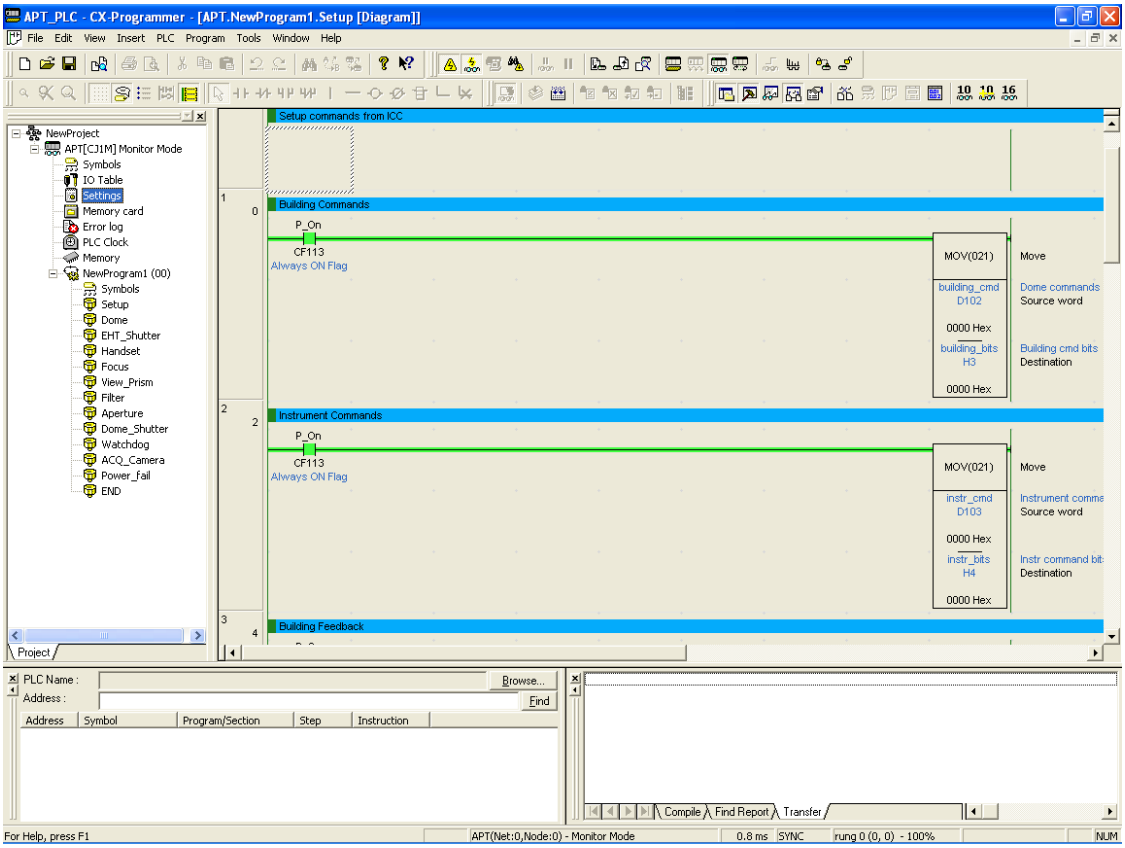
- Select Options and transfer to PLC.



Upload the changes.

Close the PLC Settings window.

- Select Monitor mode for the PLC.



- Switch the PLC off and on to make the changes relevant.

The above steps are simply a brief description of what must be done. It is important to be familiar with the system before attempting these changes.

Communications protocol

The structure of the commands issued by the host computer and the replies from the PLC are standard host link commands that are used in all Omron PLC systems. The advantage of host link commands makes the program in the PLC much simpler since the user does not have to concern him with communications. All communications with the host computer are done independent of the user program in the PLC. The user can request status of the PLC and provide commands without concern of what the PLC is doing at that moment.

Command and Response Formats

This section explains the formats for the commands and responses that are exchanged in Host Link communications.

When transmitting a command from the host computer, prepare the command data in the format shown below.

@	10^1	10^0	Header	Header	Text	FCS	FCS	*	CR
	Node No		Header Code			FCS		Terminator	

An “@” symbol must be placed at the beginning.

Node No.

Identifies the CJ2M PLC communicating with the host computer.

For this application it is always 00.

Header Code

Set the 2-character command code.

Text

Set the command parameters.

FCS

Set a 2-character Frame Check Sequence code. This is explained later.

Terminator

Set two characters, "*" and the carriage return (0x0D) to indicate the end of the command.

Response Format

The response from the CJ2M is returned in the format shown below.

@	10^1	10^0	Header	Header	16^1	16^0	Text	FCS	FCS	*	CR
	Node No		Header Code		End Code			FCS		Term.	

@, Node No., Header Code

Contents identical to those of the command are returned.

End Code

The completion status of the command (e.g., whether or not an error has occurred) is returned.

Text

Text is returned only when there is data such as read data.

FCS

The set 2-character Frame Check Sequence is returned.

Terminator

Set two characters, "*" and the carriage return (0x0D) to indicate the end of the response.

FCS (Frame Check Sequence)

When a frame is transmitted, an FCS is placed just before the delimiter or terminator in order to check whether any data error has been generated. The FCS is 8-bit data converted into two ASCII characters. The 8-bit data is the result of an EXCLUSIVE OR performed on the data from the beginning of the frame until the end of the text in that frame (i.e., just before the FCS). Calculating the FCS each time a frame is received and checking the result against the FCS that is included in the frame makes it possible to check for data errors in the frame.

Eg

@	1	0	R	S	0	0	0	1	**7**	**1**	*	CR
	Node No		Header Code		Text				FCS		Terminator	

FCS Calculation Range →

Character	Hex Value	Leftmost	Rightmost
@	40	0100	0000
1	31	0011	0001
0	30	0011	0000
R	52	0101	0010
S	53	0101	0011
0	30	0011	0000
0	30	0011	0000
1	31	0011	0001
Calculation results		0111	0001
FCS		**7**	**1**

Converted to hexadecimal.

Handled as ASCII characters.

End Codes

The End codes are in Response from the command issued.

End Code	Contents	Cause	Corrective Measures
00	Normal completion		
01	Not executable in RUN mode	PC is in run mode	Check the relation between the command and the PC mode.
02	Not executable in Monitor mode	PC is in monitor mode	
04	Address Over	Area's highest address exceeded	Check the program.
0B	Not executable in Program mode	Command cannot be executed when PLC in Program mode	This code is not presently being used.
13	FCS Error	FCS error. Wrong calculation or noise	Check the FCS calculation method. If there was influence from noise, Transfer the command again.
14	Format Error	Command format is wrong	Check the format and transfer the command again.
15	Entry Number Data error	Read/write area specification is wrong.	Correct the areas and transfer the command again
16	Command not Supported	Command does not exist	Check the address and instruction.
18	Frame length error	Max frame length exceeded	Divide the command into multiple frames.
19	Not executable	Items to read not registered for composite command (QO)	Execute QQ to register items to read before attempting batch read.
23	Memory write protected	Memory is write protected in PLC	Change the setting in the PC Setup (DM 6602).
A3	FCS error in transmit data	This error was generated while a command extending over more than one frame was being executed	Check for corrupted frames, correct if necessary, and try the transfer again
A4	Format error in transmit data		
A5	Data error in transmit data		
A8	Frame length error in transmit data		
Other		Influence from noise	Transfer the command again

Commands that the Host Computer can issue.

To simplify the communications between the host computer and the PLC system for the Super Wasp Roof Controller, the number of commands is kept to a minimum.

- A single command to check PLC status and a command to set the correct mode of operation is required.
- One command is used to pass instructions to the PLC, with one response.
- One command to request status. All the Control status info is returned.

PLC Status request - MS

This command request the Status of the PLC, not the Roof status.

@	0	0	M	S	5	E	*	cr
	Node No		Header Code		FCS		Terminator	

Status Request Response;

If the system is in Monitor-Mode, which is required for proper operation of the PLC-system, then the response will be as follow.

@	0	0	M	S	0	0	0	3	A	8	2	4	*	cr
	Node No		Header		End Code		Status Data				FCS		Terminator	
							16^3	16^2	16^1	16^0				

The status data breakdown:

The status data must be seen as a four hex characters

16^3				Meaning	Action
0	0	0	0	Normal	
			1	Fatal error	PLC failure
1				FALS Error	Reset PLC

16^2				Meaning	Action
0	0				
		0	0	Program Mode	Issue Monitor command
		1	0	Run Mode	Issue Monitor command
		1	1	Monitor Mode	

16^1				Meaning	Action
1					
	0	0	0	No program Memory	PLC failure
	0	0	1	10Kbytes	
	0	1	0	20Kbytes	

PLC Status write – SC

Use this command to change to PLC to Monitor mode if required. The PLC is configured to be in Monitor mode normally. This can fail if the system has been off for an extended period of time (> 20 Days). Ask the person who maintains the system to re-apply the standard configuration using the CX-programmer.

@	0	0	S	C	0	2	5	2	*	cr
	Node No		Header		Mode Data		FCS		Terminator	

Status write Response:

@	0	0	S	C	0	0	5	0	*	cr
	Node No		Header		End Code		FCS		Terminator	

The above response will be returned if the command was executed normally.

An end code of 14 (format error) will be returned if the length of the command is incorrect.

An end code of 15 (entry number data error) will be returned if the mode data is out of range.

End code (Hex) Contents

00 Normal completion

13 FCS error

14 Format error

15 Entry number data error

18 Frame length error

19 Not executable

21 Not executable due to CPU Unit CPU error.

Request Roof Status – RD:

The memory locations in the PLC reserved for communications with the ICC are Data memory (DM) 100 to 105 for ICC commands to the Roof Controller and DM150 to DM153 for Roof Controller status to ICC.

This command is used to request the Status of the Roof Controller.

All the statuses of the system are returned.

@	0	0	R	D	0	1	5	0	0	0	0	3	5	1	*	Cr
	Node No		Header		Beginning Word				No of Words				FCS		Terminator	

SSC Status Response

The PLC will respond with a standard string with the three words (12 characters) in the following way.

@	0	0	R	D	0	0	D^ 3	D^ 2	D^ 1	D^ 0	. .	. .	. .	. .			*	cr
	Node		Header		End Code		Read data (1 Word)				Read Data 2nd word. Continues until all read				FCS		Terminator]	

An End Code of 00 indicates normal completion of the command.

End code (Hex) Contents

00 Normal completion

13 FCS error

14 Format error

15 Entry number data error

18 Frame length error

21 Not executable due to CPU Unit CPU error.

The structure of the Data read is explained in the SUPPER WASP – PLC COMMAND STRUCTURE notes.

Note: The first word will be a hexadecimal representation of all of the bits that are set and the second and third words will be a BCD representation of the power closure and pc coms failure delays.

Write ROOF Commands – WD:

This command is the most difficult command to construct. All the different instructions that can be issued to the Roof Controller happen here and they are always issued together. It is important to be sure that you issue your commands with previous settings intact.

Some of the Roof commands only have to be issued once and then they can revert to their 'off' state on the next issue of a command. Some commands will have to be issued in the required state every time. These differences will be discussed in the SUPPER WASP – PLC COMMAND STRUCTURE.

@	0	0	W	D	0	1	0	0	D^3	D^2	D^1	D^0	.	.	.	.			*	cr
	Node		Header		Beginning Word				1st Word data				2nd Word. Continues for 3 words total				FCS		Terminator	

The commands for the Roof are written to memory locations D-0100 to D-105 (6 words).

The structure of the Data write is explained in the SUPPER WASP – PLC COMMAND STRUCTURE.

Note: Only 3 of the 6 words are used. The first word needs to be a hexadecimal equivalent of the bits that need to be set and the other 2 words need to be BCD values between 0 and 9999.

Roof command response

The PLC will respond with a standard end code of 00 for normal completion.

@	0	0	W	D	0	0	5	3	*	cr
	Node No		Header		End Code		FCS		Terminator	

An end code of 14 (format error) will be returned if the length of the command is incorrect or the first word of write data is not in the first frame.
An end code of 15 (entry number data error) will be returned if the specified write data exceeds the data area boundary, the beginning word is not specified in BCD, or the write data is not hexadecimal. (An end code of A5 will be returned instead of 15 for non-hexadecimal write data in multiple command frames.)

End code (Hex) Contents

00 Normal completion
01 Not executable in RUN mode
13 FCS error
14 Format error
15 Entry number data error
18 Frame length error
21 Not executable due to CPU Unit CPU error.
A3 Aborted due to FCS error in transmit data
A4 Aborted due to format error in transmit data
A5 Aborted due to entry number data error in transmit data
A8 Aborted due to frame length error in transmit data

Appendix B: PLC Command Structure

D-Memory	Description	State	Duration	
100.0	Close Roof	1 = Close	As req.	HR1.0
100.1	Open Roof	1 = Open	As req.	HR1.1
100.2	mains/Battery	1 = Mains	As req.	HR1.2
100.3				HR1.3
100.4	Rain on/off	1 = Rain Det. On	As req.	HR1.4
100.5				HR1.5
100.6				HR1.6
100.7				HR1.7
100.8	Req Control	set to 1 briefly	once	HR1.8
100.9				HR1.9
100.10				HR1.10
100.11				HR1.11
100.12	Accept Power delay	1 = Load	Once	HR1.12
100.13	Accept Comms delay	1 = Load	Once	HR1.13
100.14				HR1.14
100.15	Watchdog Reset	1	Always	HR1.15
101	Delay before power closure 0-9999Sec		Once	
102	Delay before PC comms failure closure 0-9999Sec		Once	
103	Reserved			
104	Reserved			
105	Reserved			

Table 1: Data from Control PC

D-Memory	Description	State	
150.0	Roof Closed	1 = Roof Closed	HR6.0
150.1	Roof Open	1 = Roof Open	HR6.1
150.2	Roof moving	1 = Roof Moving	HR6.2
150.3	Roof Remote/Manual	1 = Roof remote control 0 = Manual	HR6.3
150.4	Raining	1 = Raining	HR6.4
150.5	Forced Rain Closure	1 = Forced closure due to Rain	HR6.5
150.6	Building temp High	1 = Building temperature is high	HR6.6
150.7	Extractor fan on	1 = Extractor fan is swicthed on	HR6.7
150.8	Motor Stop Pressed	1 = Stop pressed	HR6.8
150.9	Roof AC motor status	0 = AC Motor OK 1 = AC motor tripped	HR6.9
150.10	Roof motor in use	0 = AC motor in use 1 = Battery motor in use	HR6.10
150.11	Close Proximity	1 = Proximity triggered	HR6.11
150.12	Power Failure	1 = Mains Failure	HR6.12
150.13	Forced Power closure	1 = Mains Failure Forced Closure	HR6.13
150.14	Open Proximity	1 = Proximity triggered	HR6.14
150.15	Door Sensor	1 = Door Open	HR6.15
151	Power delay feedback		
152	comms delay feedback		
153	Reserved		

Table 2: Data to Control PC