Dome Control Unit

(DCU)

Technical User Manual

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1 Contents

2 Introduction

The Dome Control Unit (DCU) is a National Instruments compatRIO-9042 controller. Controller specifications are shown next

Figure 2.1: National Instruments cRIO-9042

Property	**Value**
CPU	Intel Atom E3940 (1.6 GHz)
FPGA	Xilinx Kintex-7 7K70T
Number of slots	4
Number of Ethernet ports	2
Number of RS-232 ports	1
Number of RS-485/422 ports	1
USB Ports	3

Table 2.1: cRIO-9042 General Specifications

Next figure shows a simplified internal scheme of the CCU.

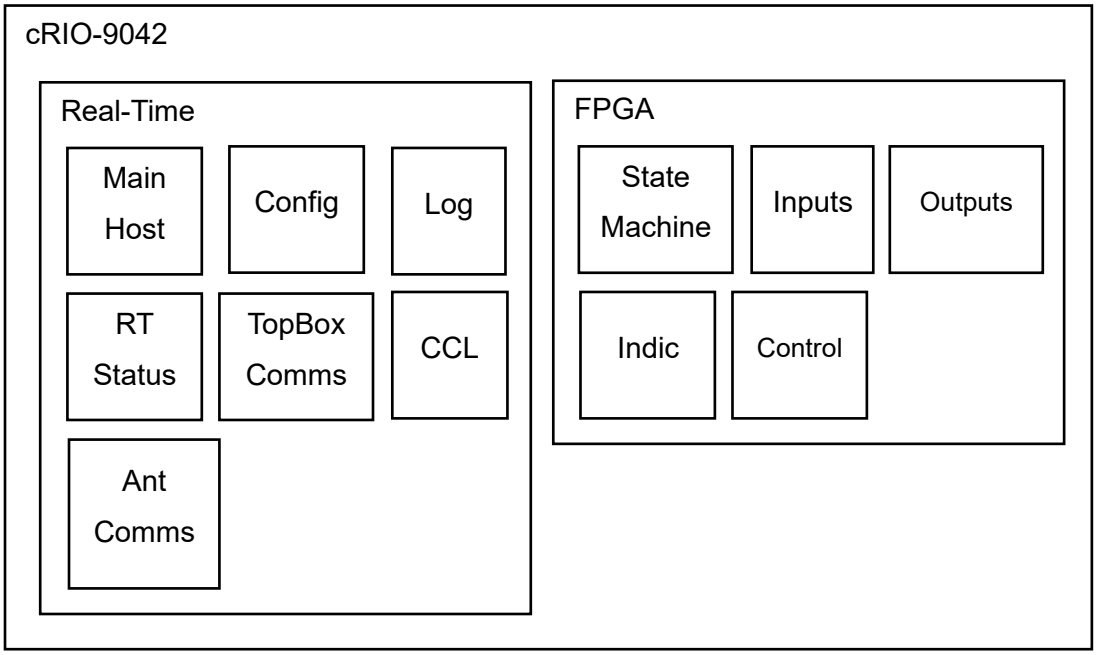

Figure 2.2: Central Control Unit Simplified Scheme

The functionality of the cRIO-9042 controller is categorized into two distinct sections: Real-Time and FPGA.

FPGA manages sensor signal measurement, control logic processing, and sends actions to motor drivers.
The Real-Time processor manages command communication, configuration, data logging, and telemetry.

3 Field Programmable Array (FPGA)

3.1 Digital Inputs

The DCU acquires digital control signals directly to FPGA using a NI-9375 C module on slot 1 (M1). The NI-9375 is a 12/24 V 16 channel 143 MHz digital inputs and 16 channels 2 kHz digital outputs. Dome application only uses M1 digital inputs at 1 kHz.

Digital inputs are `em-stop-btn` (emergency stop), `close-btn` (close shutter main door), `open-btn` (open shutter main door), `up-btn` (close shutter lower door), `down-btn` (open shutter lower door), `forward-btn` (forward dome), `reverse-btn` (reverse dome), `home-sensor` and `force-stop-btn` (force stop).

All digital inputs use a 10 milliseconds debounce.

3.2 Digital Outputs

The DCU generates output digital signals directly from FPGA to dome motor VDF using a NI-9481 C module on slot 2 (M2). The NI-9481 is a 1A @ 60 VDC, 4 channel SPST electromechanical relay module.

For VDF, 3 digital signals are generated: `Forward Dome`, `Reverse Dome` and `High-Speed`.

3.3 Encoder Input

The DCU acquires the encoder position directly to FPGA using a SEA-9510 C module on slot 4 (M4). The SEA-9510 is an EnDat encoder interface module and is configured for a Bus Speed of 1 MHz and 1 kHz data sampling.

Encoder module generates 2 signals: `enc-counts`, which is the current encoder counts; and `enc-status`, which is the internal EnDat status of encoder.

3.4 State Machine

The State Machine is the primary control component responsible for generating digital control outputs for the dome VDF. It operates as a loop running at 1 kHz, executing sequential control logic to manage different operational states.

The State Machine consists of three sequential processing blocks: Errors, Main, and Reverse Delay. The Errors block detects and latches internal errors, ensuring they persist throughout the following processing steps. These latched errors can only be cleared when a Stop mode request is issued. The Main block implements the core control logic, determining the appropriate operating mode and generating command requests. The Reverse Delay block acts as a filter, processing command requests to generate smooth control actions for the dome VDF, preventing abrupt directional changes.

Within the Main block, a command request `r(k)` is issued at each cycle `k`, which can take five values: Stop (0), Forward (1), Reverse (-1), High-Speed Forward (2), and High-Speed Reverse (-2). The Reverse Delay block incorporates an internal counter register `l(k)` and a reverse delay threshold `L`, regulating how commands are processed. The VDF command register is updated based on the following logic:

```
l(k) = 0;
if(c(k-1) == 0)
      l(k) = min(l(k-1) + 1, L);
end

c(k) = 0;
if(l(k) == L && c(k-1) == 0 || sign(r(k)) == sign(c(k-1)) && c(k-1) != 0)
      c(k) = r(k);
end
```

The reverse delay logic ensures that if the previous command was Stop (`c(k-1) = 0`), the system waits for the reverse delay threshold before setting `c(k) = r(k)`. If the preceding command was not Stop (indicating motion in any direction), the reverse delay logic is applied solely when a change in direction is detected.

3.4.1 Stop Mode

Stop mode brings the dome to a halt and allows operators to use physical buttons for high-speed forward and high-speed reverse movement. This mode serves as the foundation for all operational transitions, meaning that any change in operating mode first transitions through Stop mode before proceeding to the requested mode. While in Stop mode, the only condition that can push the system into Error mode is an emergency stop triggered either by a physical input or by TopBox.

3.4.2 Home Mode

Home mode references the encoder position to the home sensor. The process starts with a high-speed search in the shortest direction, as specified by the previous value of home position register. The dome moves in this direction until it first reaches the home sensor, at which point it immediately stops. After stopping, the system enters a brief waiting period, utilizing the reverse delay threshold to ensure that the dome has fully halted.

Once the system confirms a complete stop, the dome moves in the opposite direction at a lower speed until it reaches the home sensor again. When the dome arrives at the home sensor position for the second time, it stops precisely and writes the encoder reference register with the corresponding encoder count.

A crucial step in the homing sequence is to ensure that after reaching the home sensor at high speed, the system first stops before reversing at low speed. This precaution is necessary because the dome structure cannot halt instantly at high speed and may slide beyond the sensor, leading to incorrect position storage.

Home mode enforces a timeout threshold, which triggers an error if the homing sequence exceeds the allowed duration. Errors that can bring the system into Error mode during home mode include module errors (M1, M2, and M4), timeout errors, encoder failures, and shutdown conditions.

3.4.3 Position Mode

Position mode is employed for tracking and functions with a high-speed threshold and position tolerance. If the distance between the required position and the current position exceeds the high-speed threshold, the dome moves at high speed; otherwise, it remains in low-speed mode. The dome stops once the position error falls below the defined position tolerance.

The absolute distance `|d(k)|` between the required position `r(k)` ∈ [0,360[and the current position `y(k)` ∈ [0,360[in degrees is calculated as:

```
h(k) = max(r(k), y(k)) - min(r(k), y(k)); % h(k) = abs(r(k) - y(k))
|d(k)|= min(360-h(k), h(k));
```

To determine whether the dome should move in the forward direction, the Boolean variable `f(k)` is computed using:

$$f_k = (m_k \cdot n_k) \mid \overline{(m_k \mid n_k)}, \qquad m_k = e_k > 0, \qquad n_k = |e_k| < 180, \qquad e_k = r_k - y_k \quad (3.1)$$

Position mode operates under a configured timeout threshold, and an error is triggered if the dome fails to reach the target position within the specified time. Errors that can transition the system into Error mode during Position mode include module errors (M1, M2, and M4), timeout errors, encoder failures, and shutdown conditions.

3.4.4 Center Mode

Center mode is used to align the tape encoder to a configured center position in encoder counts. The control logic in Center mode is like Position mode, but instead of using degrees, it directly processes encoder count values. Center mode operates with a center high-speed threshold and a center tolerance to determine movement speed.

In contrast to Position mode, Center mode does not generate a timeout error condition, as the centering process may require several minutes to complete. Additionally, since the dome might need to rotate multiple full turns to reach the encoder center, imposing a time constraint would not be practical. Errors that can transition the system into Error mode during Center mode include module errors (M1, M2, and M4), encoder failures, and shutdown conditions.

3.4.5 Error Mode

The system enters Error mode when one or more errors are detected. The system remains in error mode even if the original error is no longer present. In this mode, the dome stops completely, preventing further movement. The specific errors that trigger Error mode depend on the current operational state.

To exit Error mode, the user must issue a Stop mode request, which clears internal latched errors and the error mode latch. Persistent input errors, such as an active emergency stop, will remain and must be resolved before the system can exit Error mode. If unresolved input errors persist, the system will stay in Error mode, preventing further operation.

3.5 Position Calculation

The position calculation relies on several configured parameters: `enc-step`, which defines the number of encoder counts in a full 360-degree rotation; `enc-ref`, which represents the encoder count recorded at the home sensor after executing the home command; `enc-negate`, a Boolean flag indicating whether the encoder polarity should be inverted; `home-pos`, which specifies the configured home sensor position in per-unit (P.U.) notation, where 0 P.U. corresponds to 0 degrees and 1 P.U. corresponds to 360 degrees; and `enc-counts`, the current azimuth encoder count.

```
a = enc-counts - enc-ref;
if(enc-negate)
    a = enc-ref - enc-counts;
end
b = (int) home-pos * enc-step;
az-pos = mod(a + b, enc-step) / enc-step;
```

Once the azimuth position (`az-pos`) is determined, it is converted to degrees in Real-Time processor by multiplying the value by 360 degrees.

3.6 Controls and Indicators

Several control and indicators are programmed at the top level of the FPGA VI for low-speed configuration and low-speed data acquisition from Real-Time processor.

Next, controls and indicators are provided.

Name	Category	Signal	Description
mode request	Control	Enum	Dome operation mode request. Possible request is stop, home, position and center.
reset	control	Boolean	Reset control logic loop to load new configuration and re initialize internal registers.
shutdown	control	Boolean	Enable shutdown and trigger a latched error.
Chassis Temperature	Indicator	Double	Controller chassis temperature in degrees.
mode	Indicator	U8	Internal dome mode. Stop Mode (0), Home Mode (1), Position Mode (2), Error Mode (3), Center Mode (4).
sub mode	Indicator	U8	Internal dome sub-mode.
cloud?	Indicator	Boolean	Cloud sensor.
cloud to counter	Indicator	U32	Cloud timeout counter in milliseconds.
homing wait counter	Indicator	U32	Counter in milliseconds for change from high-speed to low-speed in reverse direction in homing process.
az pos	Indicator	<±32,2>	Azimuth position in P.U. The scale is 1 P.U = 360 deg.
az enc counts	Indicator	U64	Azimuth encoder counts.
enc status	Indicator	U16	Azimuth encoder internal EnDat status.
homing?	Indicator	Boolean	Indicates if the system is in homing procedure.
az last rotation	Indicator	Enum	Indicates last dome rotation direction: none, forward, reverse.
cmd	Indicator	I8	Indicates VDF logic command after reverse delay logic block: stop (0), low-speed forward (1), high-speed forward (2), low-speed reverse (-1) and high-speed reverse (-2).
cmd request	Indicator	I8	Same as “cmd” but is the request before reverse delay logic block.
rev dly counter	Indicator	U32	Counter in milliseconds of the reverse delay block.
home sensor	Indicator	Boolean	Physical home sensor status.
env sensor	Indicator	Boolean	Physical environmental sensor status.

error?	Indicator	Boolean	Indicates internal error in dome control logic.
buttons	Indicator	Cluster	Physical buttons state. Emergency stop (em-stop), forward, reverse, open, close, up, down, force stop.
errors	Indicator	Cluster	Internal latched errors.
config	Control	Cluster	Internal configuration control.
config out	Indicator	Cluster	Current loaded “Config” configuration. To load a new configuration, reset control must be triggered.

4 Real-Time (RT)

4.1 Configuration (Config)

Configuration VIs (read and write) sets up parameters for Real-Time and FPGA. Configuration is read at system start or by a host command and written using a write configuration host command.

Configuration file is located in "`home:lvuser\natinst\LabVIEW Data\config.ini`". Next table shows configurable parameters description:

Parameter	Type	Value	Description
`WatchdogTim`	I32	`600`	Watchdog Timer in seconds for Rain sensor and host socket communication.
`DirRevDel`	I32	`4`	Dome reverse direction delay in seconds.
`Coast`	I32	`0.5`	(Deprecated) old position coast.
`HSThres`	I32	`5`	High speed position threshold for position mode.
`EncCounts360`	Double	`-`	Encoder counts per 360 degrees. Current value is 4018143232.
`EncCenter`	Double	`-`	Encoder center in counts used in Center Mode. Current value is 68719476735.
`EncCenterHs`	Double	`-`	Encoder center high-speed threshold used in Center Mode. Current value is 55807545 which is like 5 degrees.
`EncCenterTol`	Double	`-`	Encoder center position tolerance used in Center Mode. Current value is 5580754 which is like 0.5 degrees.
`HomePos`	Double	`0`	Home position in degrees used settled in Home Mode. This is the position in degrees of the home sensor.
`EncRefDeg`	Double	`0`	(Deprecated) old encoder reference position in degrees.
`EncRefCounts`	Double	`-`	Encoder reference in counts. For calculating position, the reference in counts is subtracted to current encoder position in counts.
`Tol`	Double	`0.5`	Position tolerance in degrees used in Position Mode.
`CloudEn`	Boolean	`False`	Cloud sensor enable.

AutoShutEn	Boolean	True	Autoshutdown enable. Autoshutdown flag is settled when cloud error or host communication watchdog time is settled. Autoshutdown flag is sent to TopBox through "Idle" command. Autoshutdown only affects operation of TopBox shutters and does not affect dome.
RainTim	I32	5	Rain/Cloud timeout in seconds used in auto shutdown.
AZTimeout	I32	120	Position mode timeout in seconds. Is the maximum time allowed to reach a commanded position in Position Mode.
AZEncPol	I32	1	Encoder polarity: 1 – Positive (Default), -1 – Negative. Defines the sign of the encoder current position.
TOPUDPPort	I32	17308	TopBox UDP port used for TopBox address discovery.
MainHostPort	I32	17310	MainBox TCP server port for host communication.
MainHostTO	I32	60	Host communication timeout in seconds. Timeout is the maximum allowable time between two consecutive host commands.
AZEncNoError	I32	1025	Internal encoder no error status.
AntWifi	Boolean	True	TopBox/MainBox WIFI-6 Control Link Enable.
TopAntAddr	String	-	TopBox/MainBox WIFI-6 Control Link Ip address. Default is 10.0.1.4
TopAntPort	U16	17309	TopBox/MainBox WIFI-6 Control Link TCP port.

4.2 Main Host Communication (Main Host Comms)

Main Host Communication VI is a telnet TCP server used for host communication. It uses MainHostPort as TCP server port and MainHostTO as command timeout.

For Telnet communication from LabVIEW or Python, you need to add a CR (carriage return) and a LF (linefeed) at the end of the send/read message. Telnet communication directly from windows add automatically CR and LF at the end of each command.

Not all commands have a reply. For example, certain commands need TopBox communication. In case of error, the reply protocol is "<ERROR>".

The protocol for commands is “<COMMAND>” or “<SUBCMD><SP><COMMAND>”, where “<SP>” is a space.

Main Host VI uses “main queue” to enqueue commands to Central Control Loop (CCL).

Host commands are listed below.

4.2.1 + - Full Status

Full status of the MainBox and TopBox. Reply protocol contains 27 statuses with format “<status_0><CR><LF><status_1><CR><LF>…<status_26><CR><LF>”, where “<status_k>” is a single status described in next table.

k	Format	Description
0	MAIN<SP><State><SP><Per>	TopBox main (upper) door status. The “<state>” is “{Ajar, Open, Shut, Error}” and “<Per>” is opened door from 0 (closed) to 1000 (opened).
1	DROP<SP><State><SP><Per>	TopBox dropout (lower) door status. The “<state>” is “{Ajar, Open, Shut, Error}” and “<Per>” is opened door from 0 (closed) to 1000 (opened).
2	<AutoShtdwn><SP><State>	Auto shutdown state with <AutoShtdwn>={[ON], [OFF]} and <State>=2’b<Cloud><Rain> in two digits integer decimal format.
3	<AtHome><SP><CurAZ>	<AtHome> is HOME if dome is at home position, if not is POSN. <CurAZ> is current dome azimuth position in degrees.
4	<LastRot><SP><State>	<LastRot>= {-- (None), RR (right) and RL (left)}. <State> is a 3-digit decimal integer formatted in binary as • Bit 0 (LSB): <ForwardDome> • Bit 1: <ReverseDome> • Bit 2: <CloseMainDoor> • Bit 3: <OpenMainDoor> • Bit 4: <CloseLowerDoor> • Bit 5: <OpenLowerDoor> • Bit 6: <GotoHome>

		• Bit 7 (MSB): <EMButton> <EMButton> is the logical or between MainBox and TopBox emergency buttons.
5	Dome<State>homed	The state is "Dome homed" or "Dome not homed".
6	Emergency<SP>Stop<SP>Active:<SP><Value>	Emergency stop state 0 (not emergency) and 1 (emergency), with the logical or between MainBox and TopBox emergency buttons.
7	Top<SP>Comm<SP>Link<SP>OK:<SP><Value>	MainBox and TopBox communication state, with 0 (Disconnected) and 1 (Connected).
8	Home<SP>Azimuth:<SP><Value>	Configured home position in degrees.
9	High<SP>Speed<SP>(degrees):<SP><Value>	Configured high-speed threshold in degrees used in position mode.
10	Coast<SP>(degrees):<SP><Value>	Configured Coast in degrees. This parameter is not currently used (deprecated).
11	Tolerance<SP>(degrees):<SP><Value>	Configured tolerance for position mode.
12	Encoder<SP>Counts<SP>per<SP>360:<SP><Value>	Encoder counts per 360 degrees.
13	Encoder<SP>Counts:<SP><Value>	Raw encoder counts.
14	Last<SP>Azimuth<SP>GoTo:<SP><Value>	Last commanded dome azimuth position in degrees.
15	Azimuth<SP>Move<SP>Timeout<SP>(secs):<SP><Value>	Azimuth timeout in seconds to reach commanded position in position mode.
16	Rain-Snow<SP>enabled:<SP><Value>	TopBox rain/snow sensor enable: 0 (disabled), 1 (enabled).
17	Cloud<SP>Sensor<SP>Enabled:<SP><Value>	MainBox cloud sensor enable: 0 (disabled), 1 (enabled).
18	Watchdog<SP>Reset<SP>Time:<SP><Value>	Configured TopBox watchdog time in seconds.
19	Dropout<SP>Timer:	Configured TopBox dropout timer in seconds.

	<SP><Value>	
20	Reverse<SP>Delay:<SP><Value>	Configured TopBox reverse delay in seconds.
21	Main<SP>Door<SP>Encoder<SP>Closed:<SP><Value>	Configured TopBox main encoder closed position in counts.
22	Main<SP>Door<SP>Encoder<SP>Opened:<SP><Value>	Configured TopBox main encoder opened position in counts.
23	Dropout<SP>Door<SP>Encoder<SP>Closed:<SP><Value>	Configured TopBox dropout encoder closed position in counts.
24	Dropout<SP>Door<SP>Encoder<SP>Opened:<SP><Value>	Configured TopBox dropout encoder opened position in counts.
25	Door<SP>Move<SP>Timeout<SP>(secs):<SP><Value>	Configured TopBox door move timeout in seconds.
26	Dome<SP>has<SP>been<SP>homed:<SP><Value>	Shows if the dome has been homed: `True` or `False`.

4.2.2 ? – Short Status

The same as Full Status, but from k= [0,5].

4.2.3 AEN – Azimuth Encoder Negative Polarity

Set AZ encoder to negative polarity.

4.2.4 AEP – Azimuth Encoder Positive Polarity

Set AZ encoder to positive polarity.

4.2.5 AF, OF – Disable Autoshutdown

Disable Autoshutdown.

4.2.6 AO, ON – Enable Autoshutdown

Enable Autoshutdown.

4.2.7 AT – Set Az move timeout

Set AZ move timeout in seconds for position mode. The range is [120, 600] seconds. This command follows the protocol "<TIMEOUT><SP>AT", where <TIMEOUT> is the timeout in seconds in integer format.

4.2.8 CF – Disable Cloud Shutdown

Disable cloud shutdown in Autoshutdown.

4.2.9 CFR – Read Configuration File

Read configuration file.

4.2.10 CFS – Save Configuration File

Save current configuration to configuration file.

4.2.11 CL – Close Upper Door

Close shutter upper/main door. This command requires TopBox communication.

4.2.12 CO – Enable Cloud Shutdown

Enable cloud shutdown in Autoshutdown.

4.2.13 CS – Set Coast Threshold (Deprecated)

Deprecated set coast threshold command.

4.2.14 DN – Open Lower Door

Open shutter lower/dropout door. This command requires TopBox communication.

4.2.15 DT – Set Door Move Timeout

Set shutter doors move timeout in seconds. This command requires TopBox communication. This command follows the protocol "<TIMEOUT><SP>DT", where <TIMEOUT> is the timeout in floating point format.

4.2.16 HELP – Help Text

Shows firmware version and available commands.

4.2.17 HM – Send Dome to Home

Send dome to home position. This command changes the operational dome mode to Home Mode and

4.2.18 CN – Send Dome to Encoder Center

Send dome to encoder center. This command changes the operational dome mode to Center Mode.

4.2.19 HS – Set High Speed Threshold

Set high-speed threshold in degrees for position mode. The range is [0, 10] degrees. This command follows the protocol “<THRESHOLD><SP>HS”, where <THRESHOLD> is the threshold in degrees in floating point format.

4.2.20 HZ – Define Home Position

Define the position of the home sensor in degrees. The range is [0, 360[degrees. This command follows the protocol “<HOME><SP>HZ”, where <HOME> is the position in degrees in floating point format. This value is used as an offset in calculation of dome position.

4.2.21 LF – Rotate Dome Left

Rotate dome left by degrees. The range is [0, 360[degrees. This command follows the protocol “<ANGLE><SP>LF”, where <ANGLE> is the number of degrees to rotate in floating point format.

4.2.22 LM – Set Encoder Step

Set Encoder counts in 360 degrees. The minimum value is 1. This command follows the protocol “<COUNTS><SP>LM”, where <COUNTS> is the number of counts in 360 degrees in integer format.

4.2.23 MV – Rotate to Azimuth

Rotate the dome to a position in degrees. The range is [0, 360[degrees. This command follows the protocol “<ANGLE><SP>MV”, where <ANGLE> is the desired angle in floating point.

4.2.24 OP – Open Upper Door

Close shutter upper/main door. This command requires TopBox communication.

4.2.25 RD – Set Reverse Delay

Set reverse delay in seconds. The range is [0,6[seconds. This command follows the protocol "<DELAY><SP>RD", where <DELAY> is the delay in seconds in integer format.

4.2.26 RF – Disable Rain/Snow Shutdown

Disable shutter rain/snow shutdown. This command requires TopBox communication.

4.2.27 RO – Enable Rain/Snow Shutdown

Enable shutter rain/snow shutdown. This command requires TopBox communication.

4.2.28 RS – Set Rain/Snow Activate Delay

Set shutter rain/snow activate delay in seconds. The range is [1,10] seconds. This command requires TopBox communication. This command follows the protocol "<DELAY><SP>RS", where <DELAY> is the delay in seconds in integer format.

4.2.29 RD – Rotate Dome Right

Rotate dome right by degrees. The range is [0, 360[degrees. This command follows the protocol "<ANGLE><SP>RD", where <ANGLE> is the number of degrees to rotate in floating point format.

4.2.30 SC – Sync Close

Close shutter upper/main and lower/dropout. This command requires TopBox communication.

4.2.31 SO – Sync Open

Open shutter upper/main and lower/dropout. This command requires TopBox communication.

4.2.32 AWO – Enable Control WIFI Antenna

Enable MainBox/TopBox control WIFI-6 direct link antenna.

4.2.33 AWF – Disable Control WIFI Antenna

Disable MainBox/TopBox control WIFI-6 direct link antenna.

4.3 Central Control Loop (CCL)

The Central Control Loop (CCL) is the main processing unit, operating at 10 Hz. It receive commands from the Main Queue, updates the status between MainBox and the FPGA, and sends commands to TopBox through the Top Queue.

4.4 TopBox Communication

The TopBox Communication VI establishes a connection between MainBox and the TopBox TCP server for control communication.

4.4.1 Connection Process

The `AntWifi` flag determines the TCP address and port for connecting to the TopBox TCP server. If `AntWifi = False`, the connection follows the original implementation procedure. In this case, the system first connects to a TopBox UDP socket on port `TopUDPPort` and address `234.5.6.7`. It then waits for a message with the structure "`AceDome01<SP><TCPPort><SP><TCPAddress>`", which provides the TCP server port and address required for establishing the final connection. This method utilizes the first Ethernet socket, which is connected to a general-purpose WIFI antenna integrated into the general telescope network.

If `AntWifi = True`, the system instead uses the secondary Ethernet port to connect to the TopBox TCP server via a point-to-point industrial WiFi-6 link. In this case, the system directly uses `TopAntPort` and `TopAntAddr` as configuration parameters for the connection. The primary Ethernet socket is then reserved exclusively for general access, configuration, and telemetry.

4.4.2 Command and Reply Transmission

Once the connection is established, MainBox sends commands to TopBox via the Top Queue. The command and reply protocol follow a simple format: `<length><message>`. The `<length>` field consists of a 4-byte I32 representing the length of `<message>`, transmitted in big-endian format (MSB first). This protocol applies to all configuration options.

To maintain an active connection between MainBox and TopBox while ensuring that MainBox's state remains updated in TopBox, the TopBox communication VI guarantees that at least one

command is sent to TopBox every second. This is managed using the global variable `TopConnectTime`, which stores the timestamp of the last message sent to TopBox.

If no command is sent within one second or if there is a change in MainBox's state—including status, control, configuration, or button inputs—the TopBox VI automatically sends an `Idle` command to TopBox. This mechanism ensures a continuous and synchronized exchange of information between both systems.

4.4.3 Communication

Communication between MainBox and TopBox uses a JSON encoding. This protocol allows communication with TopBox using a more flexible and platform-independent format. This method eliminates LabVIEW dependency, preventing compatibility issues between different LabVIEW versions used in MainBox and TopBox commands are structured following the schema `{"command": "String", "value": "Object"}`. 4 bytes I32 with command length in Big-Endian is prepend to each command.

Most commands in JSON format only use the "`command`" key, without a "`value`" key. However, the "`Idle`" command is the only exception, as it requires the "`value`" key to transmit additional system states. Specifically, when sending the "`Idle`" command, the "`value`" field contains MainBox information about the shutter button states, emergency stop status and shutdown flag.

In response to commands, TopBox always sends back its full system state. TopBox replies using schema `{“reply”: “String”, “value”: “Object”, “error”: {“status”: “Boolean”, “code”: “I32”, “source”: “String”}}`, where `value` is the full TopBox status in JSON format and `error` is an object used in case of errors. Reply also send 4 bytes I32 length in Big-Endian as a prefix. The received TopBox status is stored in the global variables `TopDomeCtrl`, `TopDomeStat`, and `TopConf`.

The JSON-based approach provides several advantages over the traditional method. It ensures cross-platform compatibility, allowing external applications to communicate with TopBox without requiring LabVIEW-specific data structures. It also enhances maintainability, as JSON messages are easier to parse and modify without dependency on LabVIEW-specific APIs. Additionally, JSON improves system scalability, making it easier to integrate new functionalities without modifying the entire communication protocol.

4.4.4 TCP Connection Handling

To ensure reliable communication, the system continuously monitors the TCP connection between MainBox and the TopBox TCP server. If any communication error occurs, such as a network failure or an unexpected disconnection, the system will close the TCP client socket and attempt to reconnect to the TopBox TCP server.

Additionally, if the value of `AntWifi` changes during operation, the system will close the existing TCP connection and reconfigure itself according to the new network settings. This ensures that the system always connects using the correct interface—either the general-purpose WiFi antenna when `AntWifi = False` or the point-to-point industrial WiFi-6 link when `AntWifi = True`. After closing the connection, the system will automatically initiate a new connection process based on the updated configuration.

This reconnection mechanism guarantees continuous operation and minimizes downtime, ensuring that MainBox maintains control over TopBox even in the presence of network instability or configuration changes.

4.5 Antenna Communication (Ant Comms)

The industrial WiFi 6 antenna connected to the MainBox operates as the master node of the industrial WiFi 6 mesh network. This antenna is responsible for maintaining the high-reliability wireless link used for control communication with the TopBox when the system is configured with `AntWifi = True`.

The Antenna Communication VI establishes a connection to the antenna's UDP telemetry server, which continuously transmits status information and error notifications. The VI listens to this stream of telemetry data and records relevant information in the system log.

All messages received from the antenna’s UDP server are logged using the "`ANTENNA`" key in the log file. This ensures that antenna-related events, warnings, or failures are properly tracked and available for diagnostics and analysis. The integration of the antenna telemetry into the logging system allows to monitor the state of the wireless communication infrastructure in real time.

4.6 Log Process (Log)

Log files are stored in the directory "`home:lvuser\natinst\LabVIEW Data\log.txt`" and serve as a record of system activity. All components can write to the log file using a timestamp and a string message, ensuring traceability of events and system behavior.

Each log entry follows the format "`<time><TAB><message><CR>`", where `<TAB>` represents a horizontal tab, and `<CR>` represents a carriage return. The timestamp is stored in the format "`<year>-<month>-<day>T<hour><minute><second>.<milliseconds>Z`", providing a precise chronological record of events.

The message content follows the structure "`<type><TAB><content>`", where `<type>` indicates the nature of the log entry. The possible types are `ERROR` for system faults, `INFO` for general operational messages, and `CMD` for processed commands. The `<content>` field contains the detailed information relevant to the log entry.

To ensure efficiency and manageability, the log file is updated every 1 second and can store a maximum of 50,000 lines before older entries are overwritten.

Log Process VI transmits incoming logs to Real-Time Status VI as soon as a client is connected.

4.7 Real-Time Status (RT Status)

This VI operates as a TCP server on port `700`, providing the full status of the MainBox in JSON format. The server continuously sends updated system status at a rate of 10 Hz, ensuring real-time monitoring of the MainBox.

The communication protocol follows the structure "`<length><message>`", where `<length>` is a 4-byte `I32` in big-endian format, representing the size of `<message>`, and `<message>` is the JSON-encoded MainBox status.

This Real-Time Status VI is primarily used to support a web-based graphical user interface (GUI) that displays the full current status of the MainBox.

An empty example of the JSON-formatted status sent by the server is:


```
{"time":"2025-04-
24T17:05:44.507Z","hostComms":false,"topBoxComms":true,"mainHostAddr":"","AZP
os":359.53582897782325745,"AZPosReq":0,"AZPosError":0,"AZEncCounts":106294063
754,"AZEncStatus":1025,"AZLastRot":"reverse","mode":"error","modeReq":"stop",
"subMode":0,"cmd":0,"buttons":{"EMStop":true,"forward":false,"reverse":false,
"open":false,"close":false,"up":false,"down":false,"forceStop":false},"envSen
sor":false,"homed":true,"homing":false,"homeSensor":false,"config":{"cloudEn"
:false,"AZEncNeg":false,"AZEncRef":102281101370,"AZEncStep":4018143232,"homeP
os":0,"AZTimeout":120000,"AZEncNoError":1025,"posHSThreshold":5.0000000372529
029846,"posTol":0.4999999701976776123,"cloudTimeout":5000,"revDly":4000,"AZEn
cCenter":68719476735,"AZEncCenterThreshold":55807545,"AZEncCenterTol":5580754
,"watchdogTim":600,"autoShutEn":true,"antWifi":true},"errors":{"EMStop":true,
"AZEnc":false,"AZTimeout":false,"cloud":false,"M1":false,"M2":false,"M4":fals
e,"watchdogTime":true,"shutdown":true},"logs":{"time":[],"messages":[]}}
```