



Application Note

Control AOIs for Nanotec Drives Using PDI Objects
over Ethernet/IP

Version 1.0.0

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1 Introduction

Nanotec offers a broad range of drives to control brushless DC (BLDC) motors or stepper motors. Some drives are stand-alone, wired separately to the motor to supply power and receive feedback, while others are integrated into the motor assembly for local control, requiring only Ethernet/IP and power connection (“Plug and Drive”).

Irrespective of the configuration — be it a separate drive and motor or an integrated drive and motor package — Nanotec’s Ethernet/IP-based drives operate uniformly from the PLC controller’s standpoint. They communicate with the PLC for commands and status using the same protocol, syntax, and capability.

For clarity, all Nanotec’s motor controller products will be referred to in this document as “drive”.

1.1 External documents

Prior to attempting any programming or any functions with Nanotec systems, these external documents should be read and understood:

- Nanotec *Functional Description Plug and Drive Interface* v1.0.1
- Nanotec *Plug and Drive Interface Application Note: Establishing Connection with Ethernet* v1.0.0
- Nanotec *Plug & Drive Studio Quick start guide*
- *N5 EtherNet/IP Technical Manual V3.4.0* (or specific technical manual per application)

1.2 Assumptions or basis of firmware and drive functionality

Testing and development were performed using Nanotec *N5* drive with firmware v2213- B1031134. The AOIs were developed in Rockwell *Studio 5000* rev 35.

1.3 Numerical values

Numerical values are generally specified in decimal notation. The use of hexadecimal notation is indicated by a subscript h at the end of the number.

The objects in the object dictionary are written with index and subindex as follows:

<Index>:<Subindex>

Both the index as well as the subindex are specified in hexadecimal notation. If no subindex is listed, the subindex is 00_h.

Example: Subindex 5 of object 1003_h is addressed with 1003_h:05_h, subindex 00 of object 6040_h with 6040_h.

2 AOI goal summary

The developed AOIs encapsulate the command functionality provided in the *Plug and Drive Interface* (PDI) assemblies. The AOIs provide you with easily implemented control software for Nanotec drives using Rockwell’s *ControlLogix* and *CompactLogix* controllers (programmed using Rockwell’s *Studio 5000* programming environment).

To improve end-user program development timelines, the AOI’s look and feel resemble *Studio 5000*’s built-in motion control instructions (i.e. *MAS*, *MAM*, *MSF*, etc.). Use of these newly developed Nanotec AOIs is similar to the existing instructions, so that an experienced *Studio 5000* Programmer will be able to seamlessly implement the AOIs in the same method as the existing *Studio 5000* motion instructions.

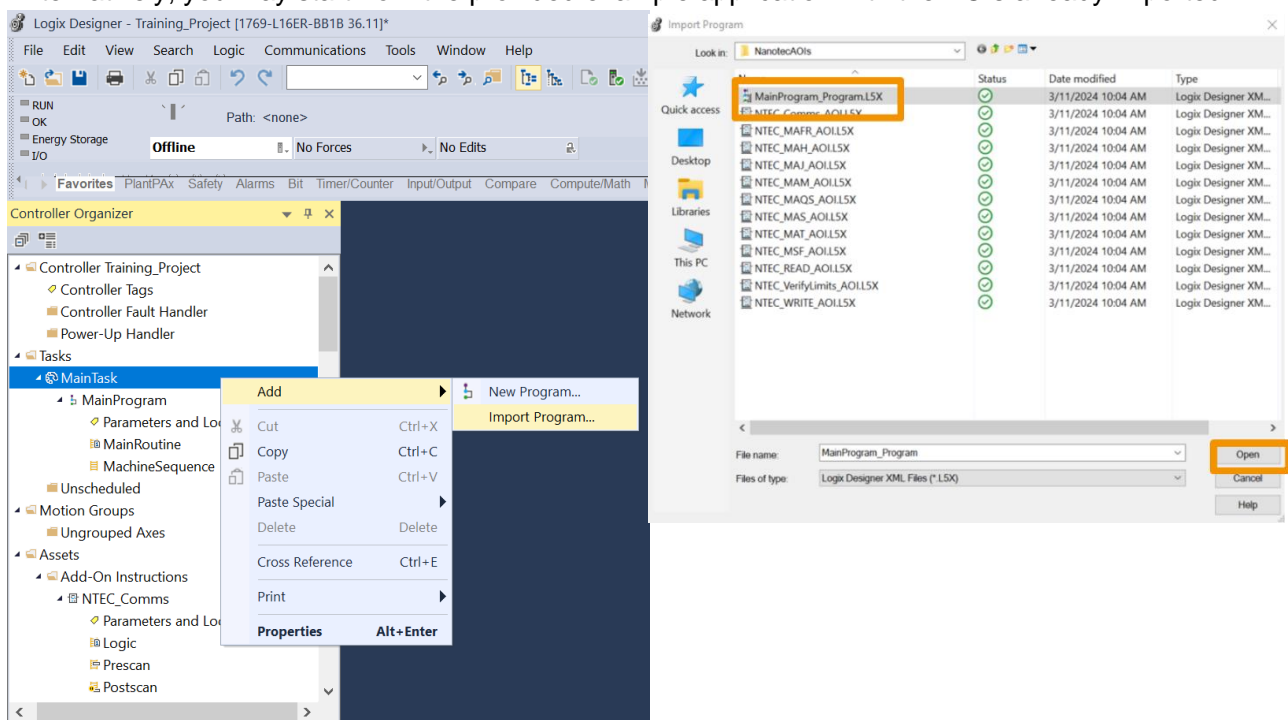
3 End user software setup

3.1 AOI Studio 5000 implementation methods and requirements

Each AOI is an independent file and can be downloaded from the Nanotec website. An example *Studio 5000* application is also available with the AOI files.

After downloading the files, you import the folder of AOI's into your specific *Studio 5000* application for your new project. These files are not imported into the *Studio 5000* environment, like EDS files are, but rather into each project's application program.

Alternatively, you may start from the provided example application with the AOIs already imported:



After importing the AOIs, you create instances of the AOIs for each control function of the drive. Only one instance of the *Communication* AOI shall be implemented in the *Studio 5000* application per drive. An instance of each type of command AOI may be created inside the *Studio 5000* application program (in the same task/program as the *Communication* AOI for that drive) for each function (i.e., *Motion Axis Stop*, *Motion Axis Home*, *Motion Axis Move*, etc.).

The one *Communication* AOI is configured to communicate with one specific drive over Ethernet/IP. This *Communication* AOI acts as the traffic cop and intermediary between the motion instruction AOIs and the drive. For this reason, it works best if the AOI tags are set up at the task/program level and all of the AOIs are inside of one task/program level.

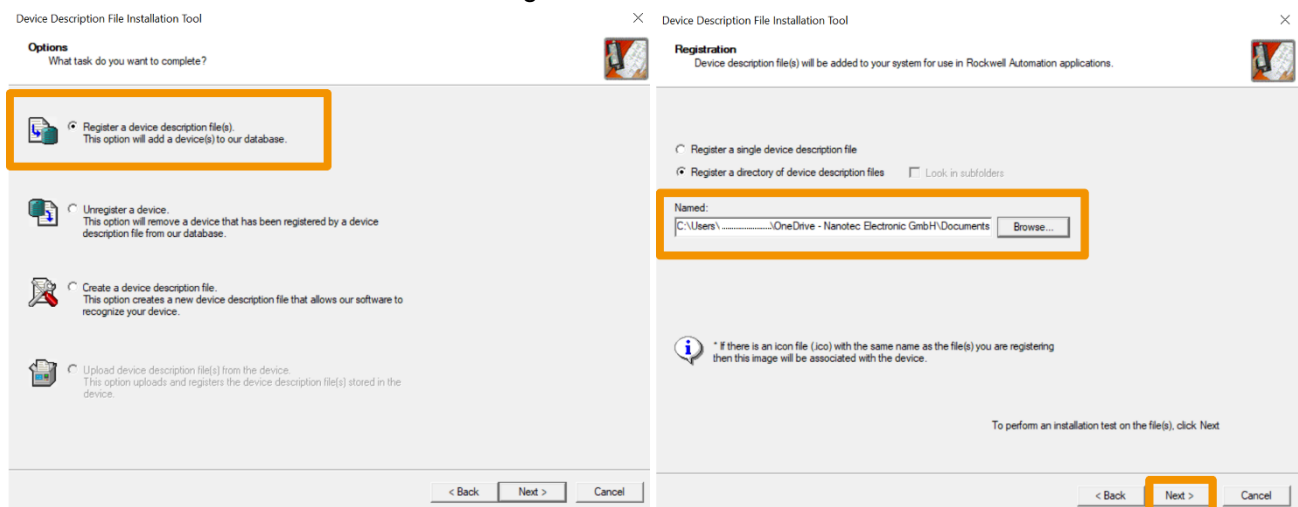
3.2 Load EDS Files

The *Studio 5000* programming PC must have the EDS files loaded into the Rockwell environment to recognize the Nanotec drive. Load the proper EDS file per the procedure in the drive's technical manual (i.e. *N5_EtherNetIP_Technical-Manual_V3.4.0* section 4.2 Commissioning Ethernet IP):

The EDS files are downloaded from Nanotec's website as part of the *Plug & Drive Studio* software download. After the software file is downloaded and unzipped, the EDS files are in the folder:

\\Downloads\\PNDS 2.1.7 Release Package\\PNDS 2.1.7 Release Package\\Firmware

When using the *EDS Hardware Installation Tool* app from Rockwell, be sure to check the box for **Register a directory of device description files** and also check the box for **Look in subfolders**. Add the whole Firmware folder of EDS files to get all of Nanotec's devices EDS files.

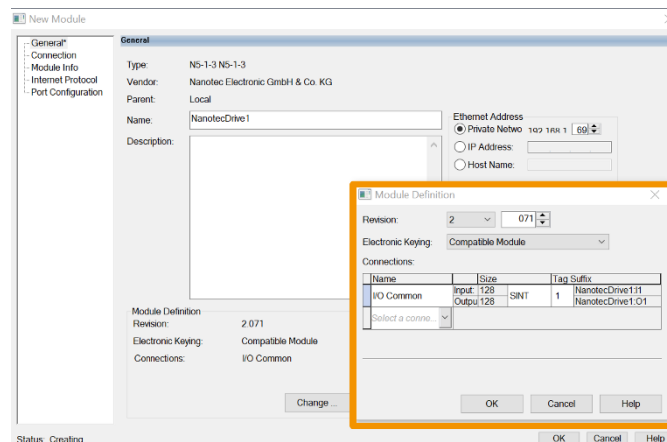


3.3 Add drive to Ethernet tree in Studio 5000

After the EDS files are loaded, follow the Nanotec technical manual's directions to add the drive to the PLC Ethernet tree in your specific application program inside of *Studio 5000* (i.e. *N5_EtherNetIP_Technical-Manual_V3.4.0*, section 4.2 Commissioning Ethernet IP).

Note that when adding the drive, in the **Module Properties** window you should click the **Change** button to configure the **Module Definition**, which is the size of the assembly objects. The EDS file provides for two configurations: I/O PDI with 8 bytes In/Out, or I/O Common with 128 bytes In/Out.

NOTE: For the use of these AOIs, the device must be setup as *I/O Common* using 128 bytes In/Out.



In the factory settings for the drive, the *Plug & Drive Interface* is *already activated*: Object 2290_h:00_h bit 0 is to "1".

3.4 Nanotec drive Ethernet address setup

Each drive must use a static IP address. User should follow the procedure in the Application Note document provided on Nanotec's website to set the IP address of the drive (*Application_Note_Establishing_connection_with_Ethernet_v1.0.0*). The same procedure to setup the Ethernet/IP address is in a shorter form in the device's technical manual (i.e. *N5_EtherNetIP_Technical-Manual_V3.4.0* section 4.1 Configuration via Ethernet).

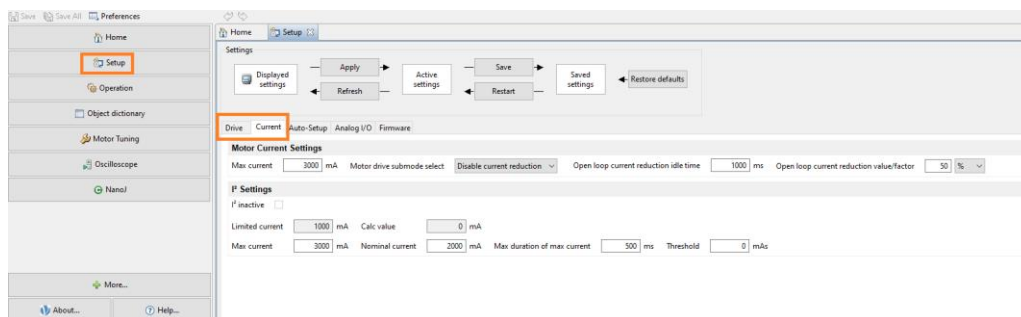
NOTE: Set the static IP address in the same subnet as the PLC Ethernet/IP subnet.

3.5 Nanotec drive setup for motor

You must enter the motor data into the drive's parameters. Use the *Plug & Drive Studio* software to set the drive's parameters.

For separate type drives (not integrated motor drives), you also need to perform an auto-setup, which detects the motor type and the attached sensors. As stated in the manual *Plug & Drive Studio Quick start guide*, Section 5.1 Auto-Setup: "Before running the auto setup, make sure all prerequisites for your controller are met. You don't need to perform the auto setup for PD (Plug & Drive) motors, it has been already performed in the factory".

Enter all of the motor's data into the fields on the *Plug & Drive Studio's* **Drive** and **Current** tabs, before going to the **Auto-Setup** tab and initiating the auto-setup.



3.6 Nanotec drive tuning and motor testing

At this point, before testing, verify the motor is not coupled to a system or a load. The motor will move, so keep the motor independent of a load to prevent damage.

After the drive is setup for the motor, and fully wired to the motor (power and feedback as applicable), follow the procedures in *Plug & Drive Studio Quick start guide*, Section 7 Motor Tuning to tune the motor.

3.7 Nanotec motor testing

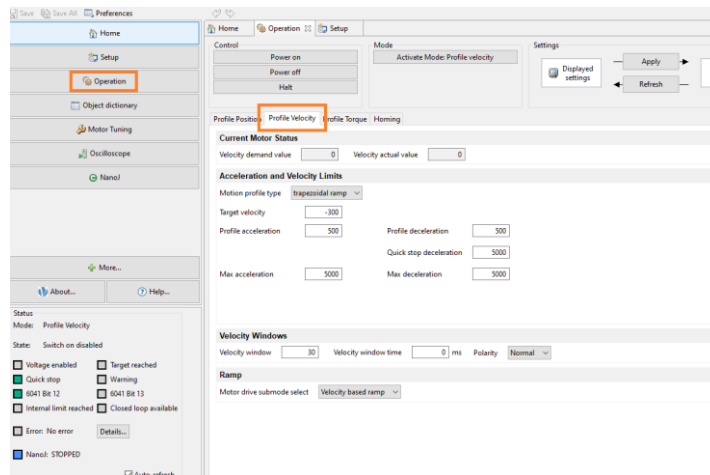
Before testing, verify the motor is not coupled to a system or a load. The motor will move, so keep the motor independent to prevent damage.

Next, use the **Operation** window and the **Profile Velocity** tab to test the motor's operation, just to visually verify the motor will run without faults.

Utilize the **Status** display in the left pane to verify the drive is ready for motion. *Quick Stop* is outlined in red when the motor is not ready to run. *Voltage Enabled* and *Closed loop available* (as applicable) should be set. **Error** must indicate *Error: No Error*.

Enter reasonable values for all fields in the **Acceleration** and **Velocity Limit** window before turning on the motor.

Press the **Activate Mode: Profile Velocity** button to initiate this mode. Then the **Power On** button to enable the power bus to the motor, and the motor should immediately start moving per the settings in the **Acceleration** and **Velocity Limit** window.



3.8 Verify the PDO mapping

Open the **Object dictionary** and look for the *EtherNet/IP PDO Mapping* objects 3501_h:xx_h (Rx) and 3601_h:xx_h (Tx). Verify that the mapping is active by checking that the correct number of entries is set as value in subindex 0 (value 20_h below). The mapping should look like this (factory setting), the *Plug and Drive Interface* objects (229x_h) marked in the table are necessary for the correct function of the AOIs:

Rx PDO Mapping		Tx PDO Mapping	
Index:Subindex	Value(Hex)	Index:Subindex	Value(Hex)
3501 _h :00 _h	20 _h	3601:00 _h	20 _h
3501 _h :01 _h	22910120 _h	3601:01 _h	22920110 _h
3501 _h :02 _h	22910210 _h	3601:02 _h	603F0010 _h
3501 _h :03 _h	22910308 _h	3601:03 _h	22920220 _h
3501 _h :04 _h	22910408 _h	3601:04 _h	60640020 _h
3501 _h :05 _h	60FE0120 _h	3601:05 _h	606C0020 _h
3501 _h :06 _h	24000120 _h	3601:06 _h	60FD0020 _h
3501 _h :07 _h	24000220 _h	3601:07 _h	60770010 _h
3501 _h :08 _h	24000320 _h	3601:08 _h	32200110 _h
3501 _h :09 _h	24000420 _h	3601:09 _h	60F40020 _h
3501 _h :0A _h	24000520 _h	3601: 0A _h	25000120 _h
3501 _h :0B _h	24000620 _h	3601: 0B _h	25000220 _h
3501 _h :0C _h	24000720 _h	3601: 0C _h	25000320 _h
...
3501:20 _h	0x24001B20 _h	3601:20 _h	25001720 _h

3.9 PLC communicating to Nanotec drive

After the PLC program is setup and the drive is setup, download the program to the PLC. Verify in the module properties that the PLC is communicating to the drive.

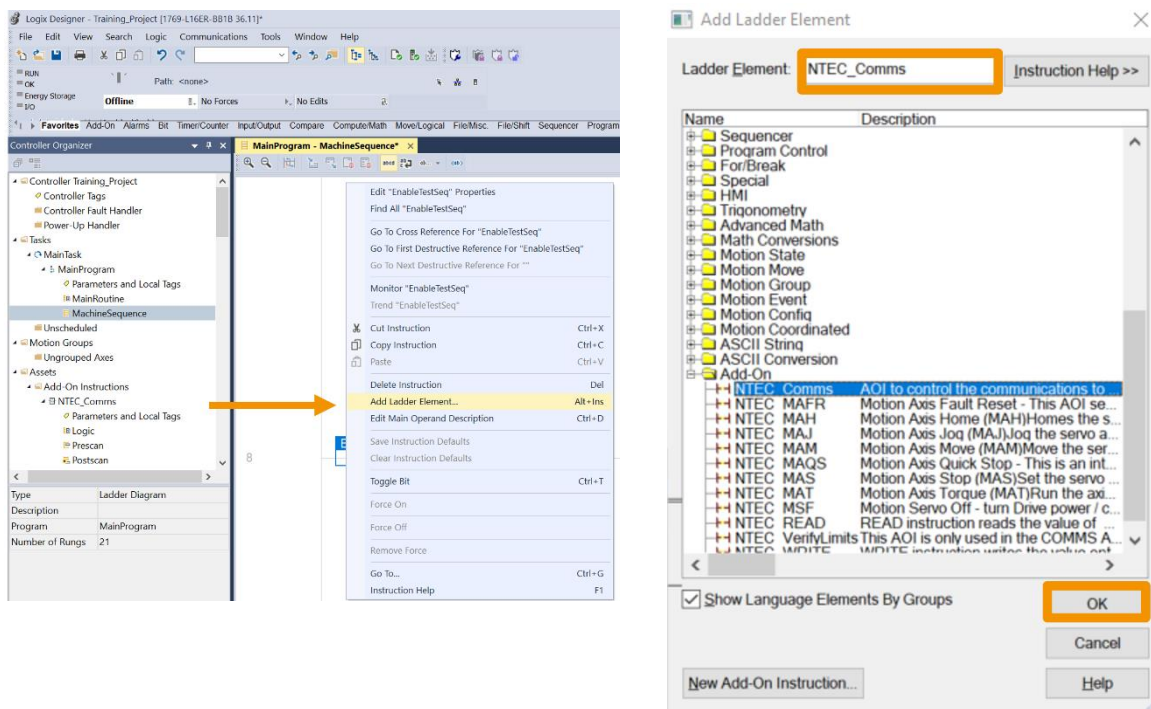
4 AOI implementation

Each of the AOIs functions as listed here.

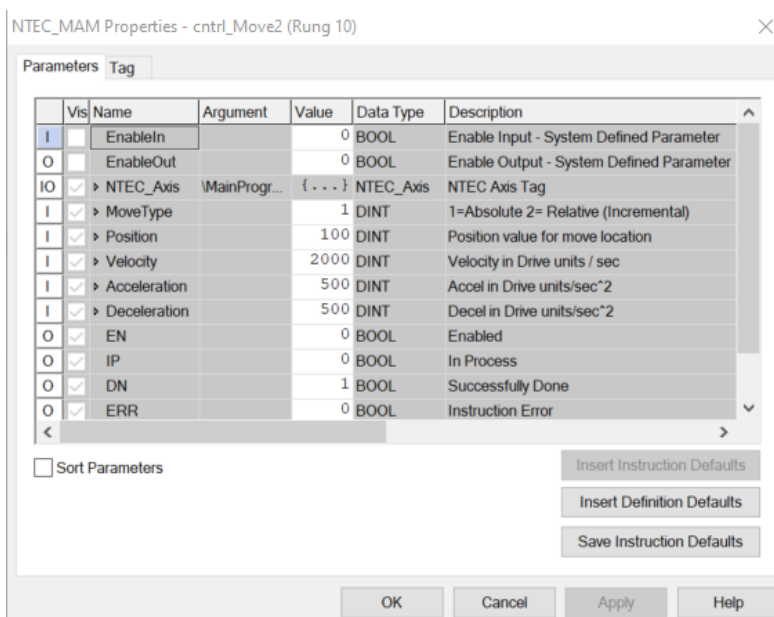
All inputs to the AOIs are BOOL or whole numbers (no floating-point inputs) and are constrained by the PDI I/O capabilities.

To add an AOI into your routine:

1. Right click and select **Add Ladder Element...**
2. Navigate or search by **NTEC**.
3. Select AOI required.
4. Click **OK**.



The AOIs all contain descriptions for each tag created as well as help files to explain the AOI inputs/outputs. Press **[F1]** for HELP.



4.1 Nanotec drive communications AOI (NTEC_Comms)

The *Communications AOI* communicates with one specific drive over Ethernet/IP using the drive's IP address. This AOI acts as the traffic cop and intermediary between the motion instruction AOIs and the drive.

All of the AOIs use a common variable for the drive control of *User Defined Tag (UDT)* type of *NTEC_Axis*. One *NTEC_Axis UDT* is created per drive. This tag is referenced in the *Communications AOI*, and every other AOI for the same drive.

This *Communications AOI* receives the internal PLC software commands from each AOI using the *NTEC_Axis UDT* and passes the commands along to the drive. This AOI allows only one command to process at a time. Once a command AOI (i.e., *Motion Axis Move (NTEC_MAM)*) trigger initiates a command in the *Communications AOI*, any other command is buffered until the first command is completed (FIFO). The exception is the *Quick Stop (NTEC_MAQS)* which will act as an interrupt to stop all ongoing commands and initiate the Quick Stop command.

The *Communications AOI* receives the drive's status registers per the PDI definition and populates these into the *NTEC_Axis UDT* tag in the PLC. Command AOIs also utilize these *NTEC_Axis UDT* status bits to know that commands have been executed and are complete.

If the drive faults, then the *Communication AOI* sets the drive's status to "Faulted" and will not accept any motion commands. The fault must be cleared before any motion command may be executed.

4.1.1 AOI Fault Codes

1	Enable input changed to False during sequence due to drive Fault or Offline.
2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive.
4	Command timeout – no acknowledge from the drive after command was sent.
5	Read Error – no value sent from drive after Read command.
6	Programming error – drive outputs for PDI Command not zero at start of new command.
7	Error reading the preset limits from the drive: Position, Velocity, Accel, Decel, Torque limits.

4.2 Motion Servo Off AOI (motor de-energized) (NTEC_MSF) (PDI-Cmd = 1)

Turning the drive "OFF" is this AOI's function, which blocks the power stage of the drive. OFF state is defined as blocking the drive's power stage to remove power from the motor.

4.2.1 AOI Fault Codes

To successfully execute this function, the drive must be in an ON state, otherwise the AOI simply finishes as the drive is already OFF.

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.3 Motion Axis Fault Reset AOI (NTEC_MAFR) (PDI-Cmd = 2)

This AOI attempts to reset any current faults in the drive.

If the fault is ongoing and cannot be reset, then the fault state will persist after the AOI has executed. But this function will execute and return with a *Done (DN)* bit after sending the fault reset command to the drive.

4.3.1 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
10	Communications Failed to drive.
11	Drive Fault during the Fault Reset sequence
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.4 Motion Axis Quick Stop AOI (NTEC_MASQ) (PDI-Cmd = 3)

This AOI stops any on-going motion using the drive's quick-stop-ramp parameter, which is setup in the drive using the *Plug & Drive Studio* software (rather than the ramp deceleration of the current motion). If the drive is commanding a *JOG*, *Position Move*, *Torque*, or *Home* command, this AOI will decelerate motion to a stop and transition to *Switch On Disabled* state (utilizing value in object 605Ah=2 as the definition for the stop type).

After completion of this AOI command, the motor will be in an OFF state and power will be removed from the motor.

The *Motion Axis Quick Stop AOI* command is an interrupt in the drive *Communications AOI* to any ongoing commands and clears the command buffer.

This *NTEC_MASQ* command may be used for a quick stop prior to powering off the drive in a Category 1 Stop sequence for an Estop.

4.4.1 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
4	Timeout Error – the motor did not power off.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.5 OD-Read AOI (NTEC_READ) (PDI-Cmd = 14)

This AOI retrieves the actual value from any object in the drive's object dictionary. The index and sub-index of the object are inputs into the AOI. The value of the object is returned as an output from the AOI.

4.5.1 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.

12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.6 OD-Write AOI (NTEC_WRITE) (PDI-Cmd = 15)

This AOI writes the value of any object from the drive's object dictionary. The index and sub-index of the object are inputs into the AOI. The value to write into the object is also an input into the AOI.

4.6.1 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.7 Motion Axis Homing AOI (NTEC_MAH) (PDI-Cmd = 17 and 18)

This AOI commands the drive to “home” the axis. Homing is the process of setting the encoder position to a specific value matched at a physical location, thus establishing an origin for the drive's physical coordinate system.

There are two PDI homing commands (17 and 18), and both functions are incorporated into this Homing AOI.

One input into the AOI is the *Home Type*: “Immediate”, “Sensor”, or “Block”.

4.7.1 Immediate Home (CMD = 17)

Immediate Home triggers the “homing on current position” command PDI-Cmd = 17.

With this command, the current physical position of the servo axis is set to the “Position” input value to the AOI. This value is a variable input into the AOI by the program and is sent over as the *SetValue1* for the command.

4.7.2 Home to a Sensor / Block (CMD = 18)

All homing parameters must be pre-set in the drive using the *Plug & Drive Studio* software, in the **Operator** window, on the **Homing** tab, prior to triggering this AOI function on a drive. The parameters must match up to the type of homing selected in the *NTEC_MAH* AOI.

For purposes of this AOI development, the homing methods 3 to 6 using the home switch were implemented and tested. All homing methods per the *N5 Technical Manual* are theoretically possible, with the specific homing method as one of the numeric inputs to the AOI: 1 to 14, 17 to 30, 33 to 34. This specific homing method is sent over as the *SetValue3* for this command.

If the homing selection input to the AOI is “Blocking”, the AOI sends the negative of the *Homing Method* to the drive as *SetValue3*.

4.7.3 Homed Status

The status bit for “Homed” in the *NTEC_Axis* UDT for the specific drive is set upon successful homing completion and remains set until an encoder fault or power cycle on the drive is experienced.

4.7.4 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.8 Motion Axis Move AOI (NTEC_MAM) (PDI-Cmd = 20 and 21)

Absolute and relative incremental moves are both incorporated into one *Motion Axis Move* AOI, in order to better match the Rockwell *Studio 5000* instruction. A selection for move type is an input to the AOI instruction.

The AOI has inputs for *Move Type* (“Absolute” or “Incremental”), *Target Position*, *Maximum Velocity*, *Acceleration*, and *Deceleration*. All inputs are in the user defined units as per the drive’s parameter setup in *Plug & Drive Studio* software.

4.8.1 Actual Position Status

While in *Profile Position* mode, the drive status returns the actual position of the motor axis, in user defined units, in the *PDI-Return Value*. This value is exposed in the *NTEC_Axis* UDT for use in the *Studio 5000* application program.

4.8.2 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
4	Command Error after Accel value was sent to the drive.
5	Command Error after Decel value was sent to the drive.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.9 Motion Axis Jog AOI (NTEC_MAJ) (PDI-Cmd = 23)

This AOI commands the drive to perform a Jog motion. Jog motion is a *Profile Velocity* mode move without a specific position target. The drive accelerates the motor to the velocity in the AOI while the Jog AOI is enabled. To stop a Jog motion, a Stop AOI must be triggered (*NTEC_MAS*). Or if the drive faults, the drive stops servo motion.

The AOI has an input for *Velocity*, *Acceleration*, and *Deceleration*. All inputs are in the user defined units as per the drive’s parameter setup in *Plug & Drive Studio* software.

4.9.1 Actual Velocity Status

While in Jog (*Profile Velocity* mode), the drive status returns the actual velocity of the motor axis, in user defined units, in the *PDI-Return Value*. This value is exposed in the *NTEC_Axis* UDT for use in the *Studio 5000* application program.

4.9.2 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
4	Command Error after Accel value was sent to the drive.
5	Command Error after Decel value was sent to the drive.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.10 Motion Axis Torque AOI (NTEC_MAT)

This AOI activates *Profile Torque* mode in the drive. The drive must be configured for closed loop operation.

The AOI has inputs for *Target Torque* (whole units in 0.x% of rated torque), *Torque Slope* (rate of change), and *Maximum Velocity*. All inputs are in the user defined units as per the drive's parameter setup in *Plug & Drive Studio* software. Rated torque is derived from the *Max Current* (amps) for the motor, as configured in *Plug & Drive Studio* software on the **Setup** window in the **Current** tab. Max torque is in tenths of % of rated torque in 203B_h:01_h (500=50%).

After this AOI instruction executes, the axis continues to run in *Torque Mode* until a Stop (*NTEC_MAS*) is executed.

4.10.1 Actual Torque Status

While in *Profile Torque* mode, the drive status returns the actual torque of the motor in tenths of %, in the *PDI-ReturnValue*. This value is exposed in the *NTEC_Axis* UDT for use in the program.

4.10.2 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
4	Command Error after Torque Slope value was sent to the drive
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

4.11 Motion Axis Stop AOI (NTEC_MAS) (PDI-Cmd = 23, velocity = 0)

Stopping any on-going motion is the function of this AOI. If the drive is commanding a Jog, Move, Torque, or Homing command, this AOI utilizes a ramp to brake the motion to a stop and hold position, maintaining an ON state of the motor. This command uses *Profile Velocity*, with a commanded velocity of zero.

The AOI has an input for Deceleration. All inputs are in the user defined units as per the drive's parameter setup in *Plug & Drive Studio* software.

After completion of this AOI, the motor will be in an ON state, holding controlled position with motor power, and be ready for new motion commands (i.e. *Motion Axis Move* (*NTEC_MAM*)).

4.11.1 AOI Fault Codes

2	Input parameter range error – review and fix input parameters.
3	Command Error response from the drive after command sent.
4	Command Error after Decel value was sent to the drive.
10	Communications Failed to drive.
11	Drive Fault during this AOIs command sequence.
12	Quick Stop triggered by software outside of this AOI.
13	Command Error response from the drive.
14	Enable input changed to False during sequence due to drive Fault or Offline.

5 Liability

This application note is based on our experience with typical user requirements in a wide range of industrial applications. The information in this document is provided without guarantee regarding correctness and completeness and is subject to change by Nanotec without notice.

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