

# NI 951x C Series Modules Object Dictionary

This document contains the NI 951x C Series drive interface modules vendor extensions to the object dictionary.

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## Input/Output & Feedback Objects

### Position Actual Value (PDO, Index 0x6063)

Format	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Encoder counts	$\pm (2^{31} - 1)$	Yes	0x0	NI 951x

#### Description

Provides the position feedback from the primary encoder or Encoder 0.

### Actual Velocity (PDO, Index 0x606C)

Format	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Module clock ticks*	$\pm (2^{31} - 1)$	Yes	0x0	NI 951x
* 1 module clock tick is 25 ns.						

#### Description

Provides the actual motor velocity calculated as the number of module clock ticks between encoder counts of Encoder 0. This value is set to zero if the module clock ticks between the encoder counts are larger than the specified **Zero-Velocity Threshold** (SDO, Index 0x2206). This value is positive when the motor is moving in the forward direction.

### Sensor Selector Code (SDO, Index 0x606A)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
Signed16	RW	N/A	0–1	No	0	NI 9516

#### Description

0 = Provides the actual velocity value from the position encoder / primary feedback device  
1 = Provides the actual velocity value from the velocity encoder / secondary feedback device

This object is used in conjunction with the **Feedback Mode** in the **Module Control Object** (PDO, Index 0x2210). The feedback selects the source of the primary feedback.

### Auxiliary Position (PDO, Index 0x2200)

Format	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Encoder counts	$\pm (2^{31} - 1)$	Yes	0x0	NI 9516

#### Description

Provides the motor position in encoder counts derived from the auxiliary feedback device, which is Encoder 1 for the NI 9516.

## Auxiliary Velocity (PDO, Index 0x2201)

Format	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Module clock ticks*	$\pm (2^{31} - 1)$	Yes	0x0	NI 9516
* 1 module clock tick is 25 ns.						

### Description

Provides the actual motor velocity calculated as the number of module clock ticks between encoder counts of Encoder 1. This value is set to zero if the module clock ticks between the encoder counts are larger than the **Zero-Velocity Threshold** (SDO, Index 0x2206). This value is positive when the motor is moving in the forward direction.

## Velocity & Acceleration Format (SDO, Index 0x2202)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	N/A	No	0x0	NI 951x

### Description

Configures the data format for **Trajectory Velocity** (PDO, Index 0x2601) and **Trajectory Acceleration** (PDO, Index 0x2602) as floating point or fixed-point.

Bit	Description
0	Velocity & Acceleration Format 0 = 32-bit floating point 1 = fixed-point 16.16 (LV 32.16)
1-7	Reserved

## Capture Position (PDO, Index 0x2204)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Encoder counts	$\pm (2^{31} - 1)$	Yes	0x0	NI 951x

### Description

Provides the encoder position where the reference position or the high-speed capture input occurred.

## Compare Position (PDO, Index 0x2205)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	W	Encoder counts	$\pm (2^{31} - 1)$	Yes	0x0	NI 951x

## Description

Specifies the encoder position at which to output a position compare output. For periodic position compare outputs, this specifies the starting position. Specify the position compare output type using the **Module I/O Configuration** object (SDO, Index 0x2220)

## Zero-Velocity Threshold (SDO, Index 0x2206)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	Module clock ticks*	1 – 0x7FFFFFFF	No	0x17D78400	NI 951x
* 1 module clock tick is 25 ns.						

## Description

Defines the **Zero-Velocity Threshold** in module clock ticks. If the time between encoder ticks/updates is equal to or greater than this value, the velocity is reported as zero.

## Module Control (PDO, Index 0x2210)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	W	N/A	N/A	Yes	0x0	NI 951x

## Description

Enables and disables special functionality on the dedicated I/O pins and controls the status of the general-purpose module I/O. This object also contains the Master Heartbeat. This object is bitmapped as follows:

Bit	Description
0	Compare Enable: 0 = Disable (Default) 1 = Enable* * Edge sensitive enable. A '0' to '1' transition is required to enable compare. For single-point compare, Compare is automatically disabled after a compare event. To re-enable, the enable must first transition to '0' and then '1.'
1	Capture Enable: 0 = Disable (Default) 1 = Enable* * Edge sensitive enable. A '0' to '1' transition is required to enable capture. Capture is automatically disabled after a Capture event. To re-enable, the enable must first transition to '0' and then '1.'
2	Capture Condition: 0 = Active Transition (Default) 1 = Inactive Transition

Bit	Description
3–6	Capture Source: 0000 = High Speed Position Capture Input (Default) 0001 = Index 0010 = Forward Limit 0011 = Reverse Limit 0100 = Home 0101 = Digital Input 0 0110 = Digital Input 1 0111 = Digital Input 2 1000 = Digital Input 3
7–8	Motion Feedback Mode: 00 = Encoder 0 is primary feedback (Default) 01 = Reserved 10 = Encoder 1 is primary (Option available only on NI 9516) 11 = Reserved
9	Position Error clear: 0 = Do not Clear (Default) 1 = Clear * Edge sensitive clear. A '0' to '1' transition clears the latch.
10	Forward Limit Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
11	Reverse Limit Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
12	Home Limit Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.

Bit	Description
13	Digital Input 0 Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
14	Digital Input 1 Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
15	Digital Input 2 Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
16	Digital Input 3 Latch Clear 0 = Do not Clear (Default) 1 = Clear * Level sensitive clear. A '0' keeps the latch cleared.
17	Compare Output Control Used for the raw state of the Position Compare output when the <b>Compare Mode</b> in the <b>Module I/O Configuration</b> object (SDO, Index 0x2220) is set for raw digital output. 0 = Low (Default) 1 = High
18	Drive Enable Output Control Used for the raw state of the Drive Enable output when Drive Enable is configured as a digital output. Configure Drive Enable as a digital output using the <b>Module I/O Configuration</b> object (SDO, Index 0x2220). 0 = Off (Default) 1 = On
19	Digital Output 0 Control 0 = Off (Default) 1 = On
20	Digital Output 1 Control 0 = Off (Default) 1 = On

Bit	Description
21	Limit LED Control 0 = LED Off (Default) 1 = LED On
22–23	Reserved
31–24	Master Heartbeat 8-bit Master Heartbeat: The Heartbeat Consumer in the module is enabled immediately on transition to Operational state. When enabled the Consumer latches the Heartbeat value in this register and then expects the value to be incremented by one every <b>Heartbeat Period</b> (SDO, Index 0x2402).

## Module Status (PDO, Index 0x2211)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	N/A	N/A	Yes	0x0	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0	Position Compare Flag: 0 = No Compare Event 1 = Compare Event  Set when the current position is the compare position. When performing a periodic position compare operation it is set on the first compare event. The Position Compare Flag clears when Compare is disabled.
1	Capture Flag: 0 = No Capture Event 1 = Capture Event  Set on a capture event. The Capture Flag clears when Capture is disabled.
2	Position Capture overlap status 0 = No Overlap Error 1 = Overlap Error  If a capture event occurred when capture is enabled and one or more capture triggers are received then this flag is set. Note that in case of multiple triggers, the Capture position PDO still contains the position that was captured on the very first capture event.



Bit	Description
3	Position Compare overlap status 0 = No Overlap Error 1 = Overlap Error  In case of a periodic position compare, if the compare output pulse is still active but the next compare position is reached then the overlap status bit is set. This occurs when the <b>Compare Pulse Width</b> (SDO, Index 0x2241) is greater than the <b>Compare Period</b> (SDO, Index 0x2242).
4	Position Error Status 0 = No Position Error 1 = Position Error  Set when position error occurs. The <b>Position Error Limit Value</b> must be set using the SDO: 0x6065. Read the <b>Position Error Value</b> using the SDO: 0x60F4.
5	Forward Limit Raw Input State 0 = Off 1 = On
6	Reverse Limit Raw Input State 0 = Off 1 = On
7	Home Raw Input State 0 = Off 1 = On
8	Digital Input 0 Raw Input State 0 = Off 1 = On
9	Digital Input 1 Raw Input State 0 = Off 1 = On
10	Digital Input 2 Raw Input State 0 = Off 1 = On
11	Digital Input 3 Raw Input State 0 = Off 1 = On

Bit	Description
12	Forward Limit State Change Latch 0 = No Change 1 = Change of State
13	Reverse Limit State Change Latch 0 = No Change 1 = Change of State
14	Home State Change Latch 0 = No Change 1 = Change of State
15	Digital Input 0 State Change Latch 0 = No Change 1 = Change of State
16	Digital Input 1 State Change Latch 0 = No Change 1 = Change of State
17	Digital Input 2 State Change Latch 0 = No Change 1 = Change of State
18	Digital Input 3 State Change Latch 0 = No Change 1 = Change of State
19	Position Capture Raw Input State 0 = Low 1 = High
20–23	Reserved
31–24	Module Heartbeat 8-bit Module Heartbeat: The Heartbeat Producer in the module is enabled immediately on transition to Safe Operational state. The Heartbeat value starts from zero on enable and then increments by one every <b>Heartbeat Period</b> (SDO, Index 0x2402).

## Module I/O Configuration (SDO, Index 0x2220)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	N/A	N/A	No	0x00000040	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0–1	Compare Mode: 00 = Single (Default) 01 = Periodic 10 = Reserved 11 = Raw Digital Output
2–3	Compare Action: 00 = Pulse (Default) 01 = Set 10 = Toggle
4	Encoder Index Reference Criteria Phase A: 0 = Phase A Inactive (Default) 1 = Phase A Active
5	Encoder Index Reference Criteria Phase B: 0 = Phase A Inactive (Default) 1 = Phase A Active
6	Drive Enable Output Pin Functionality 0 = General Purpose Output 1 = Drive Enable (Default)
7–31	Reserved

## Module I/O Active State (SDO, Index 0x2221)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	N/A	N/A	No	0x000003C0	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0	Encoder 0 Phase A Active State 0 = High (Default) 1 = Low
1	Encoder 0 Phase B Active State 0 = High (Default) 1 = Low
2	Encoder 0 Index Active State 0 = High (Default) 1 = Low
3	Encoder 1 Phase A Active State 0 = High (Default) 1 = Low
4	Encoder 1 Phase B Active State 0 = High (Default) 1 = Low
5	Drive Enable Active State 0 = On (Default) 1 = Off
6	Position Capture Active State 0 = High 1 = Low (Default)
7	Position Compare Active State 0 = High 1 = Low (Default)
8	Step Active State 0 = High 1 = Low (Default)
9	Direction Active State 0 = High 1 = Low (Default)

Bit	Description
10	Analog Output Inversion 0 = Do not Invert (Default) 1 = Invert
11	Reserved
12	Forward Limit Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
13	Reverse Limit Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
14	Home Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
15	Digital Input 0 Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
16	Digital Input 1 Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
17	Digital Input 2 Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
18	Digital Input 3 Active State 0 = On (Default) 1 = Off * This only applies when the input is used with the high-speed capture circuitry.
19–31	Reserved

## Module I/O Type (SDO, Index 0x2223)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	RW	N/A	N/A	No	0x0	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0	Step Output Type: 0 = Single-Ended (Default) 1 = Differential
1	Direction Output Type: 0 = Single-Ended (Default) 1 = Differential
2	Drive Enable Output Type: 0 = Sinking (Default) 1 = Sourcing
3	Forward Limit Input Type: 0 = Sinking (Default) 1 = Sourcing
4	Reverse Limit Input Type: 0 = Sinking (Default) 1 = Sourcing
5	Home Input Type: 0 = Sinking (Default) 1 = Sourcing
6	Digital Input 0 Type 0 = Sinking (Default) 1 = Sourcing
7	Digital Input 1 Type 0 = Sinking (Default) 1 = Sourcing
8	Digital Input 2 Type 0 = Sinking (Default) 1 = Sourcing

Bit	Description
9	Digital Input 3 Type 0 = Sinking (Default) 1 = Sourcing
10	Digital Output 0 Type 0 = Sinking (Default) 1 = Sourcing
11	Digital Output 1 Type 0 = Sinking (Default) 1 = Sourcing
12–15	Reserved

### Encoder 0 Phase A and B Filter (SDO, Index 0x2230)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	Module clock ticks*	0 to 255 ticks	No	0x14 (500ns)	NI 951x
* 1 module clock tick is 25 ns.						

#### Description

Specifies the digital filter for Encoder 0 Phase A and Encoder 0 Phase B in module clock ticks. Pulses shorter than the filter time period are guaranteed to be filtered. A value of 0 disables filtering.

Recommended Encoder and Index Filter settings for common velocity settings:

Velocity (counts/sec)	Encoder Filter	Index Filter
500 k	0x28	0x14
1000 k	0x14 (Default)	0x0A
2000 k	0x10	0x08
4000 k	0x08	0x04
8000 k	0x04	0x02
16000 k	0x02	0x01
20000 k	0x01	0x01

## Encoder 0 Index Filter (SDO, Index 0x2231)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	Module clock ticks*	0 to 255 ticks	No	0xA (250ns)	NI 951x
* 1 module clock tick is 25 ns.						

### Description

Specifies the digital filter for Encoder 0 Index. Pulses shorter than the filter time period are guaranteed to be filtered. A value of 0 disables filtering.

## Encoder 1 Phase A and B Filter (SDO, Index 0x2232)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	Module clock ticks*	0 to 255 ticks	No	0x14 (500ns)	NI 9516
* 1 module clock tick is 25 ns.						

### Description

Specifies the digital filter for Encoder 1 Phase A and Encoder 1 Phase B. Pulses shorter than the filter time period are guaranteed to be filtered. A value of 0 disables filtering.

## Position Capture Filter (SDO, Index 0x2233)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	0 – 5	No	0x01	NI 951x

### Description

Specifies the digital filter for the high-speed Position Capture input. Pulses shorter than the filter time period are guaranteed to be filtered.

Register Value	Filter Setting
0x00	50 ns
0x01 (Default)	100 ns
0x02	500 ns
0x03	1 $\mu$ s
0x04	10 $\mu$ s
0x05	100 $\mu$ s



## Limit Filters (SDO, Index 0x2234)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	N/A	No	0x00	NI 951x

### Description

Specifies the digital filters for the Forward Limit, Reverse Limit, and Home inputs. Pulses shorter than the filter time period are guaranteed to be filtered.

This object is bitmapped as follows:

Bit	Description
0–1	Forward Limit Filter 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
2–3	Reverse Limit Filter 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
4–5	Home Filter 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
6–7	Reserved

## Digital Input Filters (SDO, Index 0x2235)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	N/A	No	0x00	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0–1	Digital Input 0 Filter 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
2–3	Digital Input 1 Filter 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
4–5	Digital Input 2 Filter (Only supported in NI 9512) 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms
6–7	Digital Input 3 Filter (Only supported in NI 9512) 00 = 50 $\mu$ s (Default) 01 = 500 $\mu$ s 10 = 1 ms 11 = 10 ms

## Position Compare Window (SDO, Index 0x2240)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	Encoder counts	1-255	No	0x05	NI 951x

### Description

Specifies the window for periodic position compare operations. The module will not produce another position compare output until the position is outside the **Position Compare Window** from the previous position compare output. This prevents multiple position compare outputs at the same position in case of jitter in the system. Specify the position compare type using the **Module I/O Configuration** object (SDO, Index 0x2220).

## Compare Pulse Width (SDO, Index 0x2241)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	RW	Module clock ticks*	4 to $2^{16}-1$ (65,535)	No	0x00000028	NI 951x

\* 1 module clock tick is 25 ns.

### Description

Sets the pulse width of the position compare output, when the **Compare Action** in the **Module I/O Configuration** object (SDO, Index 0x2220) is **Pulse**.

## Compare Period (SDO, Index 0x2242)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	Encoder counts	1 to $2^{20}-1$ (1,048,575)	No	0x00000010	NI 951x

### Description

Specifies the period between compare events in encoder counts when **Compare Mode** in the **Module I/O Configuration** object (SDO, Index 0x2220) is **Periodic**.



**Note** The SDO is 32 bits, but the module only supports a maximum width of 20 bits.

## Fault and System Configuration Objects

### Control Word (PDO, Index 0x6040)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	W	N/A	N/A	Yes	0x0	NI 951x

#### Description

Controls the state of the device. It can be used to enable or disable the controller, start and abort moves in all operating modes, and clear fault conditions.

This object is bitmapped as follows:

Bit	Description
0–2	Reserved
3	Axis Enable: When this bit is cleared the outputs are in the user-specified safe states.
4–6	Move Modes: <ul style="list-style-type: none"><li>• 000 = Deactivated: Indicates that the drive is disabled.</li><li>• 001 = Moving: Indicates that the axis is moving.</li><li>• 010 = Profile Complete: Indicates that the axis is profile complete.</li></ul>
7	Reset Fault. This bit must be used to clear any existing Faults in the module, if the fault conditions are no longer active.  * Edge sensitive: A '0' to '1' transition is required to clear faults.
8–15	Reserved

### Status Word (PDO, Index 0x6041)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	R	N/A	N/A	Yes	0x0	NI 951x

#### Description

Displays the current state of the device and is bitmapped as follows:

Bit	Description
0–2	Reserved
3	Fault: Set when there is a Fault. Read the <b>Manufacturer Status Register</b> object (PDO, Index 0x1002) to identify the fault.
4–9	Reserved
10	Target reached: Spline done bit

Bit	Description
11–13	Reserved
14	Axis Active: 0 = Axis is killed or disabled. 1 = Axis is enabled.
15	Reserved

## Manufacturer Status Register (PDO, Index 0x1002)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	N/A	N/A	Yes	0x0	NI 951x

### Description

This object contains all the module faults:

Bit	Fault Name	Description
0	Module Undervoltage Fault	The external power supply ( $V_{sup}$ ) exceeds the module voltage power supply specifications. Verify that the power supply is within the module specifications and that the supply is properly connected to the module.
1	Module Overvoltage Fault	The external power supply ( $V_{sup}$ ) is not connected or does not meet the minimum power supply specifications. Verify that the power supply is within the module specifications and that the supply is properly connected to the module.
2	Drive Enable Short Circuit	The drive enable output has a short circuit. Verify that the output current is within specifications and check your Drive Enable Output connections.
3	Digital Output 0 Short Circuit (NI 9512 Only)	Digital Output 0 has a short circuit. Verify that the output current is within specifications and check your Digital Output connections.
4	Digital Output 1 Short Circuit (NI 9512 Only)	Digital Output 1 has a short circuit. Verify that the output current is within specifications and check your Digital Output connections.
5	Timing Synchronization Fault	The maximum amount of jitter and/or drift in the system has been exceeded. Verify that you do not have any processes on the RT system running at a higher priority than the NI Scan Engine, and that your real-time target is not overloaded. If the problem persists, contact National Instruments technical support.

Bit	Fault Name	Description
6	Heartbeat Communication Fault	The communication between the module and the chassis has been interrupted. Verify that your system connections are correct, adjust your cabling to reduce noise on the system, and try increasing the <b>Heartbeat Period</b> (SDO, Index 0x2402).
7	Processor Watchdog Fault	A fault occurred in the module internal processor. Please contact National Instruments technical support.
8	Internal Power Supply Fault	The module has detected a failure in its internal power supply. Please contact National Instruments technical support.
9–29	Reserved	—
30–31	Current Cartridge EtherCAT State 00 = Initialization (Init) 01 = Pre-Operational (Pre-Op) 10 = Safe-Operational (Safe-Op) 11 = Operational (Op)	Current Cartridge EtherCAT State <ul style="list-style-type: none"> <li>• 00 = Init: Module power-on state. Outputs are set to high impedance.</li> <li>• 01 = Pre-Op: Module configuration state. Outputs are set to safe states. Input states are not sampled.</li> <li>• 10 = Safe-Op: Module safe or fault state. Outputs are set to safe states. Input states are sampled.</li> <li>• 11 = Op: Module is fully operational. Outputs are enabled and inputs are sampled.</li> </ul>

### Error Register (SDO, Index 0x1001)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	R	N/A	N/A	No	0x0	NI 951x

#### Description

This object is bitmapped as follows:

Bit	Description
0	Generic error. Set any time there is a module fault.
1–3	Reserved
4	Communication error: Set when there is a Heartbeat Fault.
5–6	Reserved
7	Manufacturer Specific Error: Set any time there is a module fault.

## Heartbeat Period (SDO, Index 0x2402)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	Number of scan cycles	0–255	No	0x1	NI 951x

### Description

Specifies the number of scans between two consecutive heartbeat checks, in scan cycles. If on a heartbeat check the system detects a communication error, Heartbeat Communication Fault is returned. The default setting of 1 scan cycle causes the system to be intolerant to communication errors by causing a timeout on any loss of data due to communication errors. If your system is known to have communication errors but your application can tolerate intermittent data loss due to communication errors you can try increasing the number of scans between heartbeat checks. National Instruments recommends leaving the Heartbeat Period at 1 scan for system safety. Data loss during a move could cause your motor to stall and/or jump.

A value of 0 disables the Heartbeat Period. The Module Heartbeat count rolls over once it reaches terminal count (255). The Heartbeat Consumer checking for Master Heartbeat expects the Master Heartbeat to roll over after reaching terminal count (255).

## Control Loop Adjust Threshold (SDO, Index 0x2410)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	RW	Module clock ticks*	4–255	No	0x0028	NI 951x

\* 1 module clock tick is 25 ns.

### Description

Specifies the maximum correction that can be applied to the PID or Spline Loop time to correct for scan to scan jitter or drift. Total correction in a scan = Control Loop Adjust × Number of PIDs in the Scan.



**Note** This object affects the PID loop when used with an NI 9514 or NI 9516 module, or the Spline Loop when used with an NI 9512 module.

## Safe States (SDO, Index 0x2420)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u16	RW	N/A	N/A	No	0x0A80	NI 951x

### Description

This object is bitmapped as follows:

Bit	Description
0–1	Drive Enable safe state: 00 = Off (Default) 01 = On 10 = No Change
2–3	Digital Output 0 00 = Off (Default) 01 = On 10 = No Change
4–5	Digital Output 1 00 = Off (Default) 01 = On 10 = No Change
6–7	Position Compare 00 = Low 01 = High 10 = No Change (Default) 11 = High Impedance
8–9	Step 00 = Low 01 = High 10 = No Change (Default) 11 = High Impedance



Bit	Description
10–11	Direction 00 = Low 01 = High 10 = No Change (Default) 11 = High Impedance
12–31	Reserved

### Module FPGA Firmware Version (SDO, Index 0x2430)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	N/A	N/A	No	N/A	NI 951x

#### Description

32-bit FPGA binary/firmware version number.

## Drive Operation And Status Objects

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### Steps Generated (PDO, Index 0x2550)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	Number of Steps	0 to $(2^{32}-1)$	Yes	0x0	NI 9512

#### Description

Contains the actual number of steps generated.

### Stepper Configuration (SDO, Index 0x2551)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	N/A	No	0x0	NI 9512

#### Description

Specifies the output mode and duty cycle for the stepper outputs. The value programmed into this object is bitmapped as follows:

Bit	Description
0	Stepper output mode. 0 = Step-Direction Mode (Default) 1 = CW-CCW Mode.
1	Stepper Duty Cycle. 0 = 50% (Default) 1 = 25%
2-7	Reserved

## Control Loop Objects

### Modes of Operation (SDO, Index 0x6060)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i8	RW	N/A	N/A	No	7	NI 951x Write States*: Init, Pre-Op

\* Writes to this register are only supported in Init and Pre-Operational states. An SDO write request in any other state returns an SDO Error in response. Reads are supported in all states.

#### Description

Selects the drive mode of operation. The available modes of operation are:

Value	Description
-8	Torque Mode
7	Interpolated position mode

### Modes of Operation Display (SDO, Index 0x6061)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i8	R	N/A	N/A	No	7	NI 951x

#### Description

Contains the current mode of operation.

### Position Command Value (PDO, Index 0x6062)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	W	Encoder Counts	0 to $(2^{31}-1)$	Yes	0	NI 951x

#### Description

Specifies the commanded position.

### Position Error Limit Value (SDO, Index 0x6065)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	RW	Encoder Counts	0 to $(2^{31}-1)$	No	1000	NI 951x

#### Description

Specifies the maximum allowable position error before setting the **Position Error Status** bit in the **Module Status** object (PDO, Index 0x2211).

## Position Error Value (SDO, Index 0x60F4)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	R	Encoder Counts	0 to $(2^{31}-1)$	No	0	NI 951x

### Description

Contains the amount of position error.

## PID Gains (SDO, Index 0x60FB, Sub-Index 0x00)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	N/A	25	No	25	NI 9514 and NI 9516

### Description

Specifies the total number of elements under this object. This currently returns 25.

## Position Loop Proportional Gain (SDO, Index 0x60FB, Sub-Index 0x01)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	100	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force directly proportional to the position error. Also referred to as  $K_p$ .

## Position Loop Differential Gain (SDO, Index 0x60FB, Sub-Index 0x02)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	1000	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force proportional to the rate of change (derivative) of position error. Also referred to as  $K_d$ .

### Position Loop Integral Gain (SDO, Index 0x60FB, Sub-Index 0x03)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

#### Description

Specifies the contribution of restoring force that increases with time, ensuring that the static position error in the servo loop is forced to zero. Also referred to as  $K_i$ .

### Velocity Feedback Gain (SDO, Index 0x60FB, Sub-Index 0x04)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

#### Description

Specifies the contribution of restoring force (damping) proportional to the velocity of the motor/actuator. Also referred to as  $K_v$ .

### Position Loop Velocity Feedforward Gain (SDO, Index 0x60FB, Sub-Index 0x05)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

#### Description

Specifies the contribution in the DAC command output that is directly proportional to the instantaneous trajectory velocity. Also referred to as  $V_{ff}$ .

### Position Loop Acceleration Feedforward Gain (SDO, Index 0x60FB, Sub-Index 0x06)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

#### Description

Specifies the contribution in the drive command output that is directly proportional to the instantaneous trajectory acceleration. Also referred to as  $A_{ff}$ .

## Position Loop Derivative Time (SDO, Index 0x60FB, Sub-Index 0x07)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	1 to 16,777,216	No	2	NI 9514 and NI 9516

### Description

Specifies how often (in update samples) the derivative of position error is calculated. Also referred to as Td.

## Position Loop Integral Limit (SDO, Index 0x60FB, Sub-Index 0x08)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	1000	NI 9514 and NI 9516

### Description

Specifies an upper bound for the contribution of the integral term in the PID loop. Also referred to as Ilim.

## Output Update Period (SDO, Index 0x60FB, Sub-Index 0x09)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	1 to 16,777,216	No	1	NI 9514 and NI 9516

### Description

Specifies the output update period, generally from 1 to 10, to determine the how often the control loop output updates. For a Control Loop Period longer than 1 ms, set this register as a multiple of the Control Loop Period. Also referred to as Tout.

## Secondary Position Loop Proportional Gain (SDO, Index 0x60FB, Sub-Index 0x11)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	100	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force directly proportional to the position error. Also referred to as Kp.

## Secondary Position Loop Differential Gain (SDO, Index 0x60FB, Sub-Index 0x12)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	1000	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force proportional to the rate of change (derivative) of position error. Also referred to as Kd.

## Secondary Position Loop Integral Gain (SDO, Index 0x60FB, Sub-Index 0x13)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force that increases with time, ensuring that the static position error in the servo loop is forced to zero. Also referred to as Ki.

## Secondary Velocity Feedback Gain (SDO, Index 0x60FB, Sub-Index 0x14)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

### Description

Specifies the contribution of restoring force (damping) proportional to the velocity of the motor/actuator. Also referred to as Kv.

## Secondary Position Loop Velocity Feedforward Gain (SDO, Index 0x60FB, Sub-Index 0x15)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

### Description

Specifies the contribution in the DAC command output that is directly proportional to the instantaneous trajectory velocity. Also referred to as Vff.

## Secondary Position Loop Acceleration Feedforward Gain (SDO, Index 0x60FB, Sub-Index 0x16)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	0	NI 9514 and NI 9516

### Description

Specifies the contribution in the drive command output that is directly proportional to the instantaneous trajectory acceleration. Also referred to as Aff.

## Secondary Position Loop Derivative Time (SDO, Index 0x60FB, Sub-Index 0x17)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	1 to 16,777,216	No	2	NI 9514 and NI 9516

### Description

Specifies how often (in update samples) the derivative of position error is calculated. Also referred to as Td.

## Secondary Position Loop Integral Limit (SDO, Index 0x60FB, Sub-Index 0x18)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	0 to 16,777,216	No	1000	NI 9514 and NI 9516

### Description

Specifies an upper bound for the contribution of the integral term in the PID loop. Also referred to as Ilim.

## Secondary Control Loop Period Multiple (SDO, Index 0x60FB, Sub-Index 0x19)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	RW	N/A	1 to 16,777,216	No	1	NI 9514 and NI 9516

### Description

Specifies the output update period, generally from 1 to 10, to determine the how often the control loop output updates. For a Control Loop Period longer than 1 ms, set this register as a multiple of the Control Loop Period. Also referred to as Tout.



## Setpoint Control (PDO, Index 0x2600)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	W	N/A	N/A	Yes	0x0	NI 951x

### Description

The control object for setpoint data. This object is bitmapped as follows:

Bit	Description
0–15	Torque setpoint. Only applicable when <b>Modes of Operation</b> (SDO, Index 0x6060) is set to <b>Torque Mode</b> , ignored otherwise.
16–23	Setpoint update counter. This counter is incremented when there is new setpoint data for the module. In Torque mode, this needs to be incremented every scan period. In Position mode, this needs to be incremented when there is a new Position Setpoint (and spline data).

## Trajectory Velocity (PDO, Index 0x2601)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	Counts/ sample period	$\pm 2^{24}$	Yes	0	NI 951x

### Description

Provides the output from the trajectory generator used for Vff calculation.

## Trajectory Acceleration (PDO, Index 0x2602)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	Counts/ sample period <sup>2</sup>	$\pm 2^{24}$	Yes	0	NI 951x

### Description

Provides the output from the trajectory generator used for Aff calculation.

## Setpoint Status (PDO, Index 0x2604)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	R	N/A	0 to $(2^{16}-1)$	Yes	0	NI 951x

### Description

Contains the status object for setpoint data. This object is bitmapped as follows:

Bit	Description
0–15	Actual torque output.
16–31	Reserved

## Control Loop Period (SDO, Index 0x2610)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	Module clock ticks*	See Description	No	0x7D0	NI 951x Write States†: Init, Pre-Op
<p>* 1 module clock tick is 25 ns.</p> <p>† Writes to this register are only supported in Init and Pre-Operational states. An SDO write request in any other state returns an SDO Error in response. Reads are supported in all states.</p>						

### Description

PID/Spline Loop Period: Number of module clock ticks per cycle. 1 FPGA Tick = 25 ns

Range: Control Loop Period is a non-zero value with the following range:

$$50 \mu\text{s} \leq \text{Control Loop Period} \leq 1 \text{ ms}$$



**Note** This object affects the PID loop when used with an NI 9514 or NI 9516 module, or the Spline Loop when used with an NI 9512 module.

## System Scan Period (SDO, Index 0x2611)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u32	RW	Control loops	See Description	No	0xC8 (10 ms)	NI 951x Write States*: Init, Pre-Op
<p>* Writes to this register are only supported in Init and Pre-Operational states. An SDO write request in any other state returns an SDO Error in response. Reads are supported in all states.</p>						

### Description

Specifies the total time period of the system scan cycle, expressed in number of control loop cycles. Refer to the **Control Loop Period** object (SDO, Index 0x2610).

For a given combination of Control Loop Period and System Scan Period objects, the following must hold true:

$$\text{Control Loop Period (0x2610)} \times 25 \times \text{System Scan Period (0x2611)} = \text{System Scan Time in nanoseconds}$$

## Torque Positive Limit (SDO, Index 0x2620)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i16	RW	N/A	$\pm (2^{15} - 1)$	No	0	NI 951x

### Description

Specifies the positive (maximum) voltage limit for the Drive Command output. The torque limit defines a clamp for the Drive Command output, which is useful for systems where the maximum torque output must be smaller than the +10 to -10 voltage range. The positive and negative limits can be both positive

or both negative to limit the drive command output to a unipolar range. The only restriction is that the **Torque Positive Limit** cannot be less than the **Torque Negative Limit**.

### Torque Negative Limit (SDO, Index 0x2621)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i16	RW	N/A	$\pm (2^{15} - 1)$	No	0	NI 951x

#### Description

Specifies the negative (minimum) voltage limit for the Drive Command output. The torque limit defines a clamp for the Drive Command output, which is useful for systems where the maximum torque output must be smaller than the +10 to -10 voltage range. The positive and negative limits can be both positive or both negative to limit the drive command output to a unipolar range. The only restriction is that the **Torque Negative Limit** cannot be more than the **Torque Positive Limit**.

### Torque Offset (SDO, Index 0x2622)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i16	RW	N/A	$\pm (2^{15} - 1)$	No	0	NI 951x

#### Description

Specifies the voltage by which to shift the drive command output without requiring any action from the PID loop.

### Target Position (PDO, Index 0x607A)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	RW	N/A	$\pm (2^{31} - 1)$	No	0	NI 951x

#### Description

Contains the destination position of the trajectory generator, this is used to dead zone stiction.

### Interpolated Data Record (SDO, Index 0x60C1, Sub-Index 0x00)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	R	N/A	5	No	5	NI 951x

#### Description

Contains the number of entries for interpolated data.

### Spline Data Coefficient 0 Whole (PDO, Index 0x60C1, Sub-Index 1)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
i32	W	N/A	$\pm (2^{31} - 1)$	Yes	0	NI 951x

#### Description

Specifies the whole portion of coefficient 0 for the spline polynomial used to calculate interpolated points.

### Spline Data Coefficient 0 Fraction (PDO, Index 0x60C1, Sub-Index 2)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	N/A	$\pm 2^{24}$	Yes	0	NI 951x

#### Description

Specifies the fractional portion of coefficient 0 for the spline polynomial used to calculate interpolated points.

### Spline Data Coefficient 1 (PDO, Index 0x60C1, Sub-Index 3)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	N/A	$\pm 2^{24}$	Yes	0	NI 951x

#### Description

Specifies a coefficient for the spline polynomial used to calculate interpolated points.

### Spline Data Coefficient 2 (PDO, Index 0x60C1, Sub-Index 4)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	N/A	$\pm 2^{24}$	Yes	0	NI 951x

#### Description

Specifies a coefficient for the spline polynomial used to calculate interpolated points.

### Spline Data Coefficient 3 (PDO, Index 0x60C1, Sub-Index 5)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
f32	W	N/A	$\pm 2^{24}$	Yes	0	NI 951x

#### Description

Specifies a coefficient for the spline polynomial used to calculate interpolated points.

## Control Loop Gain Set (SDO, Index 0x2650, Sub-Index 0x00)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	R	N/A	1	No	1	NI 9514 and NI 9516

### Description

Specifies the total number of elements under this object.

## Control Loop Gain Set 1 (SDO, Index 0x2650, Sub-Index 1)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	R/W	N/A	0–5	No	0	NI 9514 and NI 9516

### Description

Gain Selector Condition for the first alternative gain set.

Bit	Description
0–2	000 : None 001 : Auxiliary Feedback (NI 9516 only: Encoder 1) 010 : Acceleration 011 : Velocity 100 : Direction
3–7	Reserved

## PID Gain Format (SDO, Index 0x2651)

Type	Access	Units	Range	PDO Mapping	Default	Supported On
u8	RW	N/A	N/A	No	0x0	NI 9514 and NI 9516

### Description

Configures the data format for the PID gains to be floating point or fixed-point.

Bit	Description
0	PID Gain Format 0 = 32-bit floating point 1 = fixed-point 16.16 (LV 32.16)
1–7	Reserved

## Where to Go for Support

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The National Instruments Web site is your complete resource for technical support. At [ni.com/support](http://ni.com/support) you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

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