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cRIO ECAT S - C SERIES EtherCAT Slave

Getting Started

V0.7/25.10.2017

Revision History

Version	Date	Description	Resp.
V0.7	25.10.2017	Minor Changes – Feedback from LV Tools Network	AME
V0.6	06.10.2017	Minor Changes – Feedback from LV Tools Network	AME
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V0.2	20.07.2017	Installation instructions added	JKU
V0.1	18.07.2017	Initial Version	JKU

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KUNBUS cRIO ECAT S

Worldwide Support and Services

The National Instruments website is your complete resource for technical support. At *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.

C Series EtherCAT Slave Module

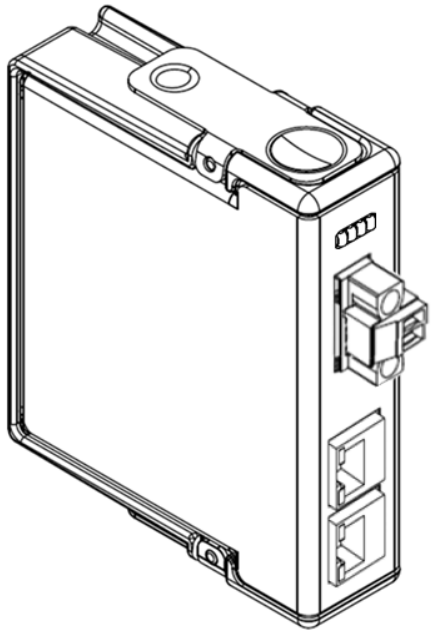


Figure 1: cRIO ECAT S Module

- Operation as EtherCAT Slave
- 2 Ethernet ports for daisy chaining additional EtherCAT slaves
- Min EtherCAT cycle time 100µS
- EtherCAT SYNC0 supported
- Max. 1024 Bytes of cyclic TX data
- Max. 1024 Bytes of cyclic RX data
- Support for CANopen over EtherCAT (CoE)
  - SDO Info
  - Complete Access
  - PDO Upload
- 24V DC external power supply required

What you need to get started

You need the following items to get started

Software

- LabVIEW 2014 or later
- LabVIEW 2014 Real-time Module AND FPGA module
- NI-RIO 2014 or later
- NI-Industrial Communications for EtherCAT 2014 or later (EtherCAT Master)
- KUNBUS *cRIO EtherCAT Slave* driver package
- KUNBUS *PDO Configurator* package

The KUNBUS packages can be downloaded from the LabVIEW Tools Network.

Hardware

- KUNBUS cRIO ECAT module
- NI cRIO chassis
- 24 V DC power supply for the module
- NI EtherCAT Master system or 3rd party EtherCAT master system

Hardware Installation and Configuration

Installing Module

This section explains how to install and remove the cRIO ECAT module from a cRIO chassis.

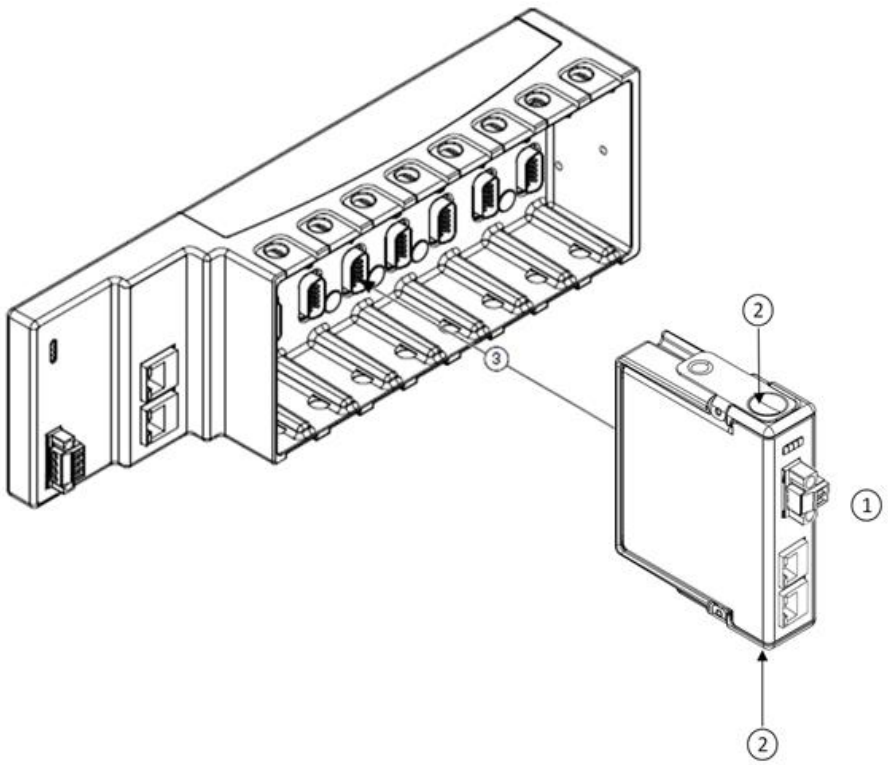


Figure 2: cRIO ECAT S Module - Installation

Complete the following steps to install the cRIO ECAT module in a cRIO chassis.

1. Make sure no external power supply is connected to the module. The chassis can be powered on when you install module(s).
2. Align the module (1) with an I/O module slot (3) in the chassis as shown in Figure 1. The module slots are labeled beginning from 1, left to right. The number of module slots depends on the cRIO chassis type.
3. Squeeze the latches (2) and insert the module into the module slot.
4. Press firmly on the front side of the module until the latches (2) lock the module into place.

cRIO ECAT Connectors and LEDs

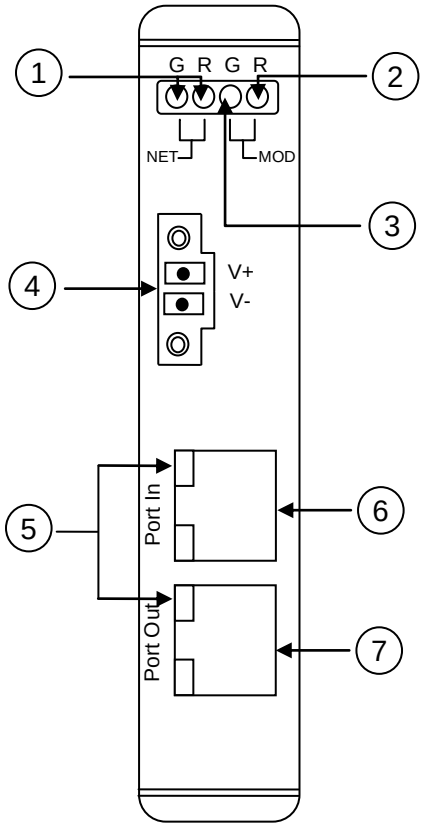


Figure 3: cRIO ECAT S – Connectors and LEDs

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1. EtherCAT LEDs (red, green)
2. Module Error LED (red)
3. Reserved LED (green)
4. Power connector
5. Ethernet LINK/ACTIVITY LED (green)
6. EtherCAT Port In
7. EtherCAT Port Out

EtherCAT LEDs

The EtherCAT LEDs indicate the module's EtherCAT device state:

LED State		Indication	Description
Green	Red		
Off	Off	INIT	EtherCAT device in 'INIT'-state (or no power)
Solid	Off	OPERATIONAL	EtherCAT device in 'OPERATIONAL'-state
Continuously blinks	Off	PRE-OPERATIONAL	EtherCAT device in 'PRE-OPERATIONAL'-state
Blinks once and pauses	Off	SAFE-OPERATIONAL	EtherCAT device in 'SAFE-OPERATIONAL'-state
Flickering	Flickering	BOOT	EtherCAT device is in 'Boot state'
Off	Solid	Fatal Event	EtherCAT network reports fatal error

Module Error LED

The module error LED indicates the module fault state:

LED State	Indication	Description
Red		
Off	No error	No error (or no power)
Continuously blinking	Invalid configuration	EtherCAT state change received from master is not possible due to invalid register or object settings.
Blinks once and pauses	Unsolicited state change	FPGA application has changed the EtherCAT state autonomously.
Blinks twice and pauses	Application watchdog timeout	EtherCAT Sync manager watchdog timeout.
Flickering	Booting error detected	Module is in exception
Solid	Application controller failure	EtherCAT network reports fatal error

Reserved LED

The reserved LED is for future use (24V DC power indication).

Ethernet LED

The Ethernet LED indicates the physical Ethernet Link state for each RJ45 connection:

LED State Green	Indication	Description
Off	No link	Link not sensed (or no power)
Solid	Link sensed, no activity	Link sensed, no traffic detected
Flickering	Link sensed, activity	Link sensed, traffic detected

Note
A simultaneous solid state of the **red** EtherCAT LED and **red** Module Error LED indicates a fatal event, forcing the EtherCAT interface to a physically passive state.

Power Connector

The module must be powered by an isolated power supply with a voltages level between 18V and 30V DC or a nominal Voltage of 24V DC.

Pin	Value
V+	+24V DC
V-	0V

The power connector plug comes with 2 wire terminals and push-in spring connections.
To connect the power supply use copper conductor wire with a wire strip length of 9 mm and a gauge of 0.14 mm² to 1.5 mm² (26 AWG to 16 AWG).
To release a wire press on the orange actuation lever of the related spring terminal.
If 2 wires are connected to 1 spring terminal, a 2-wire ferrule must be used.

RJ45 Ethernet Connection

The module has a EtherCAT input and output port.

Parameter	Value
Port In	RJ45 EtherCAT Input Port
Port Out	RJ45 EtherCAT Output Port

EtherCAT PDO configuration

The module must be configured for a specific PDO configuration offline by using the KUNBUS PDO configuration tool. The tool creates a .pdo file that must be downloaded and stored to the module.

The module can store up to 320 different PDO variables which can be mapped to EtherCAT input- and/or output data.

To open the KUNBUS PDO-configurator navigate to the LabVIEW Tools Menu >> Kunbus GmbH

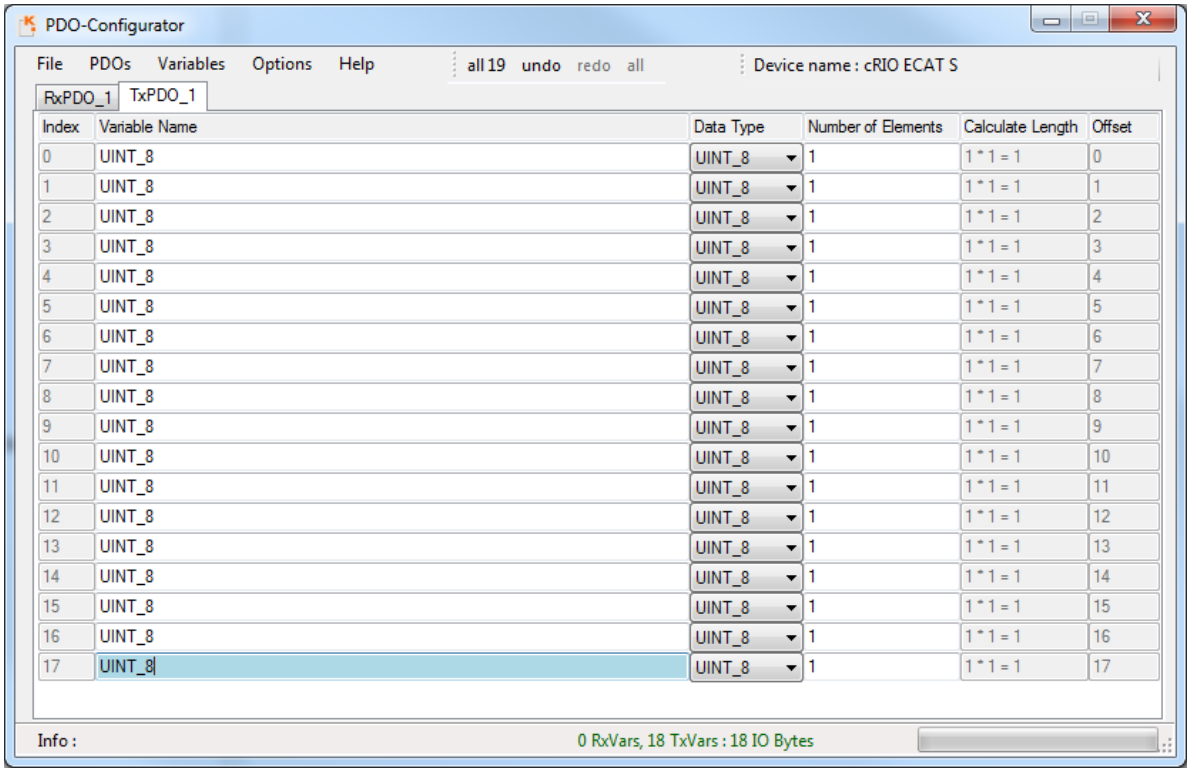


Figure 4: KUNBUS PDO-Configurator

Create a PDO configuration

The tool allows configuring RX and TX PDOs in 2 sections:

1. The (RxPDO_1) section defines PDOs for RX data received from the EtherCAT Master i.e. analog or digital output data to be written to other FPGA cRIO input- or output modules.

2. The (TxPDO_1) section defines PDOs for TX data transmitted to the EtherCAT Master i.e. analog or digital input data captured from other FPGA cRIO input- or output modules.

For every PDO an index value is automatically assigned which can be used as reference to access the PDO data directly on FPGA level.

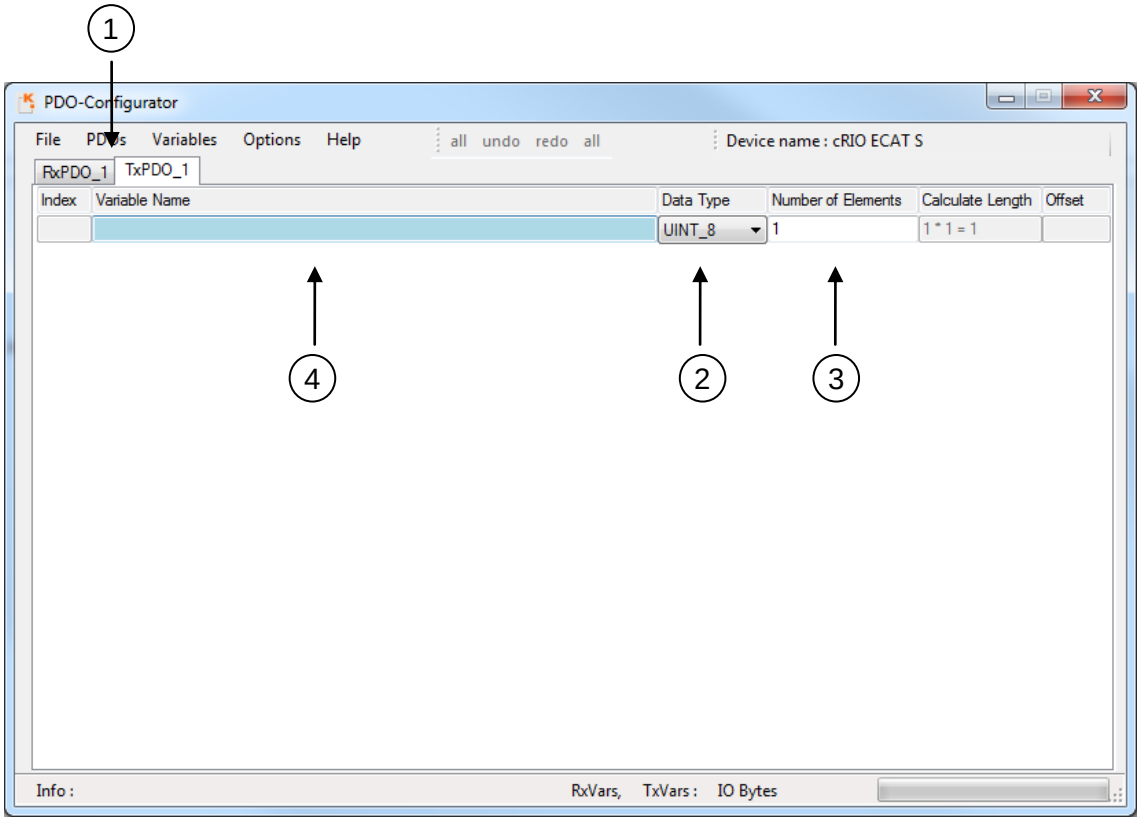


Figure 5: KUNBUS PDO-Configurator – Start screen

To define module specific PDO variables proceed with the following steps:

(1) Select the variable type section: RXPDO_1 or TXPDO_1.
RXPDO variable data is received from the module (from the EtherCAT Master).
TXPDO variable data is transmitted from the module (to the EtherCAT Master).

(2) Select PDO data format from the Data Type drop box.
Open the Data Type drop box to see all available formats.
(3) Enter the number of Data Type elements the variable is supposed to have.
This triggers the creation of array variables.
(4) Enter a variable name and press the keyboard return key.
The configured variable is now assigned an *Index* value.
The next empty variable is shown.

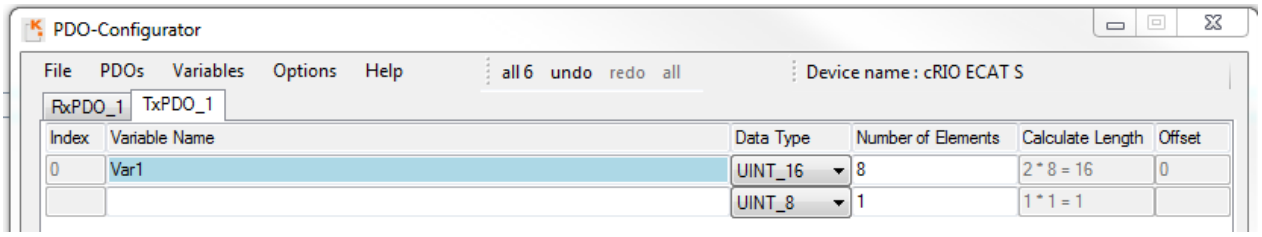


Figure 6: KUNBUS PDO-Configurator – Configured TxPDO_1 variable *Var1*

(5) Configure all required RxPDO and TxPDO variables. Use the *Variables* dialog from the toolbar to add, delete variables or move them up and down. The *PDO preferences* menu from the *Options* dialog allows configuring automatic variable name assignment.

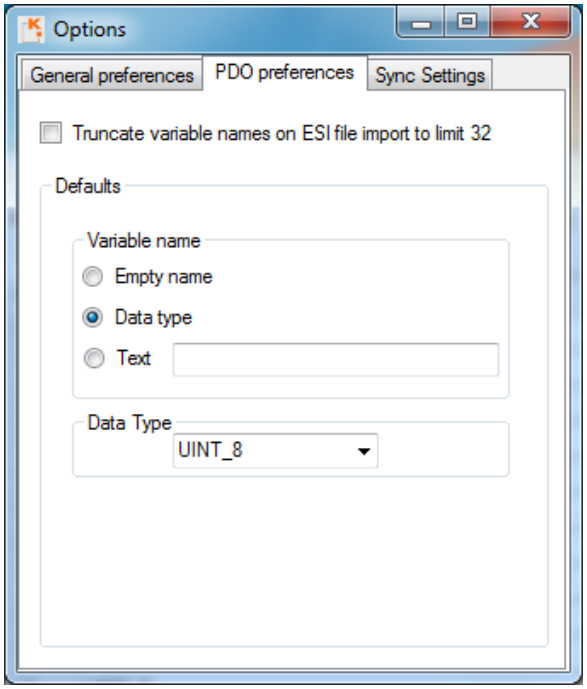


Figure 7: KUNBUS PDO-Configurator – PDO preferences menu

(6) Export the PDO configuration in .esi- and .pdo file format by using the *Export ESI & PDO file* - function from the *File* menu.
The exported esi file is used to configure the EtherCAT Master.
The exported pdo file is downloaded to the module.

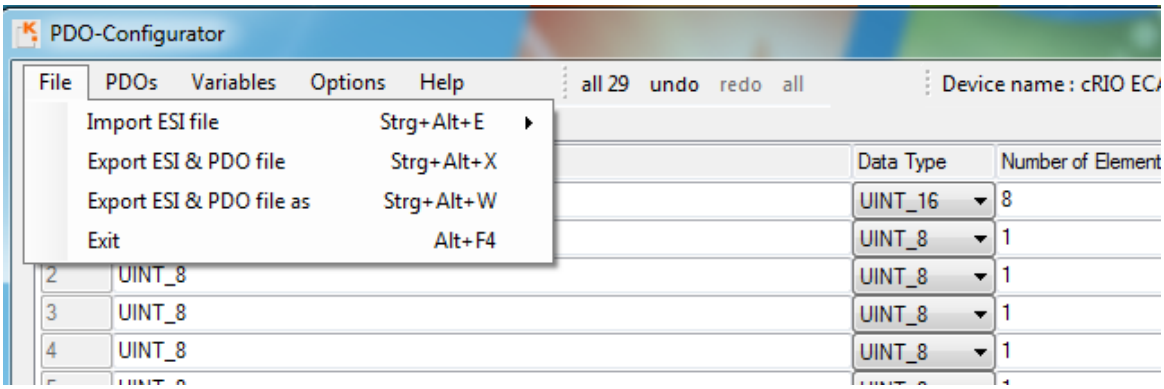


Figure 8: KUNBUS PDO-Configurator – File Import/Export functions

Download of the PDO configuration to the module

The PDO download mechanism consists of a LabVIEW RT VI and a FPGA Vi and bitfile for communication to the module. This concept allows for a stand-alone use of the RT VI as well as an integration of the download mechanism into custom RT applications.

To download the PDO configuration to the module proceed with the following steps:

(1) To open the KUNBUS PDO-Download Project navigate to the LabVIEW Tools Menu >> Kunbus GmbH

(2) Create a bitfile by compiling the *FPGA VI PDO-ConfigurationDownload(FPGA).vi* for your specific cRIO system.
- Please copy the VI *PDO-ConfigurationDownload(FPGA).vi* and the *HostToFpga* FIFO to your cRIO.
- Right-click the FPGA-VI and choose “Create Build Specification”.
- Right-click the build specification and choose “Build” to compile the VI

(3) Open the Download VI *PDO-ConfigurationDownload(Host).vi*.

(4) Assign the following parameters:
- RIO Device: cRIO IO Reference
- Path to bitfile: Location of the compiled bitfile for the Configuration Download VI.
- Path to PDO configuration file: Location of your .pdo configuration file exported by the KUNBUS PDO-Configurator.

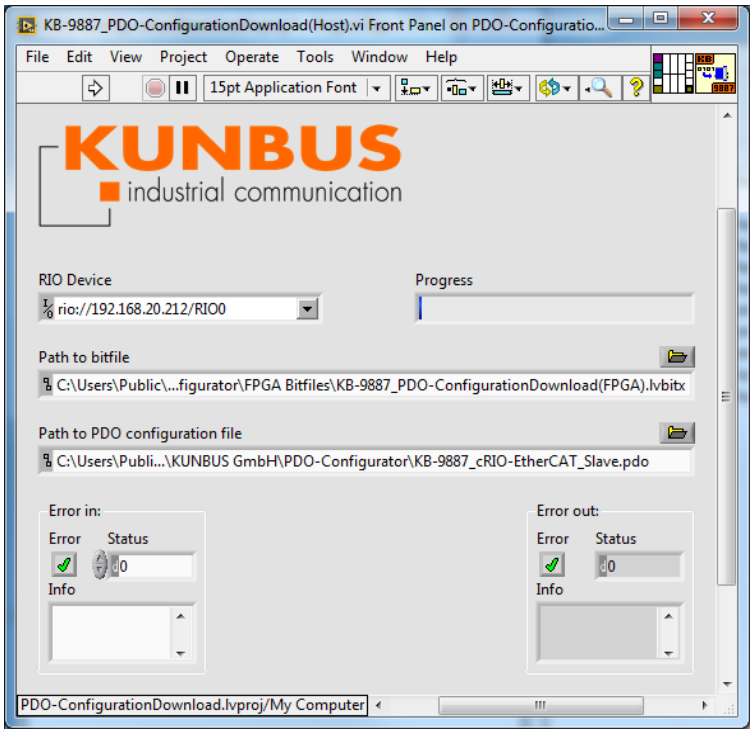


Figure 9: PDO Configuration Download VI

Running the VI, starts the download process. The progress bar indicates the download progress.

FPGA Driver module

The module's FPGA driver interface offers *property nodes* and *method nodes* for module configuration and communication.

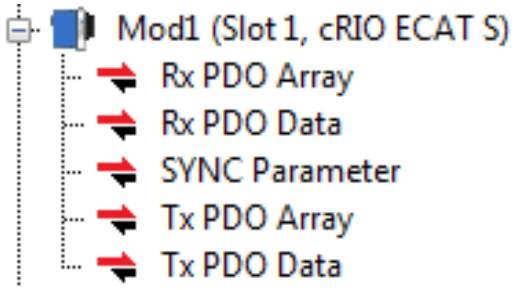


Figure 10: PDO Configuration Download VI

cRIO ECAT S Module

Property Nodes

- Vendor ID
- Module ID
- Serial Number

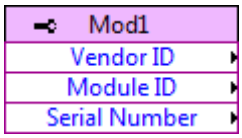


Figure 11: cRIO ECAT S Module - Property Nodes

Node	Description
Serial Number	Returns 32 bit Serial Number
VendorID	Returns 0x2013 (= KUNBUS GmbH)
ModuleID	Returns 0x4553 (= cRIO ECAT S)

Method Nodes

Reset

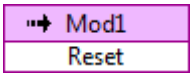


Figure 12: cRIO ECAT S Module - Method Node Reset

Node	Description
Reset	Resets the module. Use this function in combination with error code 358619 (module exception state).

Update

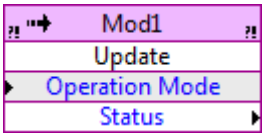


Figure 13: cRIO ECAT S Module - Method Node Update

Node	Description
Update	Transmits TX PDO variable data from FPGA to the module via 10 MHz SPI. Transmits RX PDO variable data from the module to the FPGA via 10 MHz SPI.
Operation mode	Description
TX Data	Only transmit TX PDO variable data
RX Data	Only transmit RX PDO variable data
TX/RX Data	Transmit TX PDO and Rx PDO variable data simultaneously.
Status	Description
MOD_BOOTUP	Module boots up
MOD_ERROR	Check module error LED
ECAT_INIT	EtherCAT state INIT or BOOTSTRAP or PRE-OPERATIONAL.
ECAT_SAFEOP	EtherCAT state SAFE_OPERATIONAL.
ECAT_OP	EtherCAT state OPERATIONAL.

Write PDO File

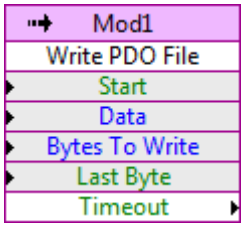


Figure 14: cRIO ECAT S Module - Method Node Write PDO File

Node	Description
Write PDO File	Internally used method by the PDO configuration download mechanism to write PDO configuration data to the module's EEPROM.

cRIO ECAT S Module Sub Items

RX PDO Data

Property Nodes

None

Method Nodes

Read Variable

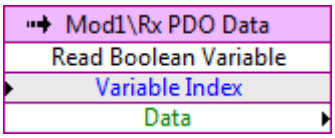


Figure 15: cRIO ECAT S Module Sub Items - Method Node Read Variable

Node	Description
Read Boolean Variable	Returns PDO variable data from FPGA memory. To get current values the UPDATE node must be executed first.
Read I16 Variable	
Read I32 Variable	
Read I8 Variable	
Read U16 Variable	
Read U32 Variable	
Read U8 Variable	
Variable Index	Description
0..320	Variable Index of PDO Variable to be read. The index matches with the PDO variable index created by the PDO configuration tool.
Data	Description
Variable data	Variable data returned

TX PDO Data

Property Nodes

None

Method Nodes

Write Variable

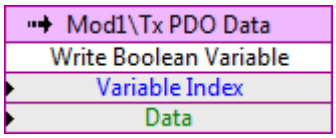


Figure 16: cRIO ECAT S Module Sub Items - Method Node Write Variable

Node	Description
Write Boolean Variable	Writes PDO variable data to FPGA memory. To transmit the variable data to the module the UPDATE node must be executed subsequently.
Write I16 Variable	
Write I32 Variable	
Write I8 Variable	
Write U16 Variable	
Write U32 Variable	
Write U8 Variable	
Variable Index	Description
0..319	Variable Index of PDO Variable to be written. The index matches with the PDO variable index created by the PDO configuration tool.
Data	Description
Variable data	Variable data to be written

RX PDO Array

Property Nodes

None

Method Nodes

Read [ ] Variable

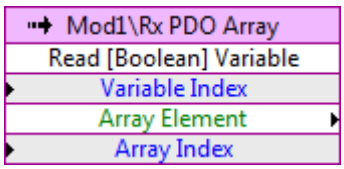


Figure 17: cRIO ECAT S Module Sub Items - Method Node Read Array

Node	Description
Read [Boolean] Variable	Returns PDO variable array data from FPGA memory. To get current values the UPDATE node must be executed first.
Read [I16] Variable	
Read [I32] Variable	
Read [I8] Variable	
Read [U16] Variable	
Read [U32] Variable	
Read [U8] Variable	
Variable Index	Description
0..319	Variable Index of PDO variable to be read. The index matches with the PDO variable index created by the PDO configuration tool.
Array Index	Description
0..65536	Index to address an element of a PDO array variable
Array Element	Description
Array data returned	Returned element of a PDO array variable

TX PDO Array

Property Nodes
None

Method Nodes

Write [ ] Variable

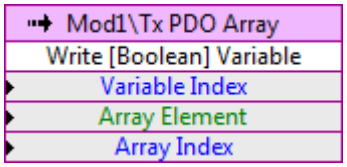


Figure 18: cRIO ECAT S Module Sub Items - Method Node Write Array

Node	Description
Write [Boolean] Variable	Writes PDO variable array to FPGA memory. To transmit the array variable data to the module, the UPDATE node must be executed subsequently.
Write [I16] Variable	
Write [I32] Variable	
Write [I8] Variable	
Write [U16] Variable	
Write [U32] Variable	
Write [U8] Variable	
Variable Index	Description
0..319	Variable Index of PDO variable to be written. The index matches with the PDO variable index created by the PDO configuration tool.
Array Index	Description
0..254	Index to address an element of a PDO array variable
Array Element	Description
Array data returned	Returned element of a PDO array variable

SYNC Parameter

Property nodes

Cycle Time / Synced with DC

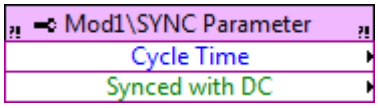


Figure 19: SYNC Parameter - Property node Cycle Time / Synced with DC

Node	Description
CycleTime	EtherCAT Cycle time calculated by the EtherCAT Master. The EtherCAT cycle time depends on various factors like network size, IO-data sizes and specific EtherCAT Master- and Slave devices.
Synched with DC	0 = Free Run No EtherCAT synchronization active 1 = SYNC Mode Master activated EtherCAT SYNC mode

Method Nodes

SYNC Signal

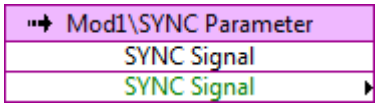


Figure 20: SYNC Parameter - Property node SYNC Signal

Node	Description
SYNC Signal	Boolean state (True, False) of digital SYNC signal. The SYNC signal is a high level active pulse with a pulse width of min. 5µS and max. 50% of the network cycle time. In EtherCAT SYNC mode the FPGA application must use this method to detect the rising edge of the SYNC pulse.

Error Handling

For all property- and method nodes error handling has to be enabled to receive error information via standard error in and error out terminals.

Error Codes

LabVIEW system error codes

Code	Error	Description	Counter measures
65536	Module Communication Error	Module is removed or invalid.	Check module installation
65537	Incorrect Module Status	Module reports an incorrect module status.	Check module installation. Power cycle the module and cRIO system.

Module specific error codes

Code	Error	Description	
358619	Module exception state	Module is in exception state and must be rebooted.	Power cycle the module. Use method RESET to reboot the module.
358618	SPI communication error	10Mhz SPI communication between chassis and module is out of order.	Check module installation. Replace module. Replace cRIO chassis.
358617	Internal error	Internal EtherCAT controller error.	Contact customer support.

FPGA Driver specific error and warning codes

Code	Error	Description	
358601	Parameter error	A parameter passed to a method node has a wrong value or is out of range. Typical examples: - Indexed PDO Variable has wrong format. - Variable index does not exist. - Array Index is too large.	Correct wrong parameter.
Code	Warning	Description	
358600	Process data not valid	- RX PDO Variable data are not valid due to module is not in EtherCAT operational state - TX PDO Variable data cannot be updated due to module is not in EtherCAT operational state	Check EtherCAT Master or Network connection

EtherCAT Communication

The module supports non-synchronized as well as synchronized EtherCAT SYNC0 communication. In synchronized mode, the module provides a digital signal SYNC signal to the FPGA API, which can be used by the FPGA application to synchronize the cyclic I/O read/write functions with all additional module based digital or analog inputs- and outputs.

EtherCAT non-synchronized mode

The non-synchronized mode is enabled by default. No additional configuration is required.

EtherCAT SYNC0 synchronization mode

To synchronize the module based inputs and outputs with the EtherCAT Master Sync 0 requests the module can detect Sync 0 timing signals.

Configuring SYNC0 synchronization mode

The following system specific parameters must be configured in the PDO configuration tool before creating the configuration files:

Min Cycle

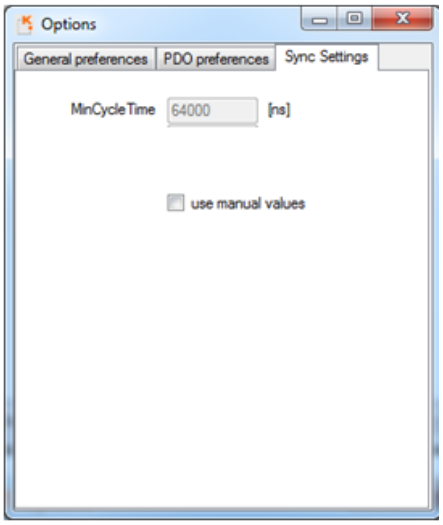


Figure 21: KUNBUS PDO-Configurator – Settings for SYNC timing parameters

Min Cycle time:

Time value in nanoseconds, the FPGA application needs at least to process all input- and output data

MinCycleTime(ns) = OutputProcessing(nS)
+ InputProcessing(nS)
+ additional FPGA code execution time (nS)

CycleTime

Network Synchronized EtherCAT Cycle time provided by the EtherCAT Master
The calculated value can be read from the FPGA API property node CycleTime.

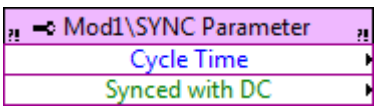
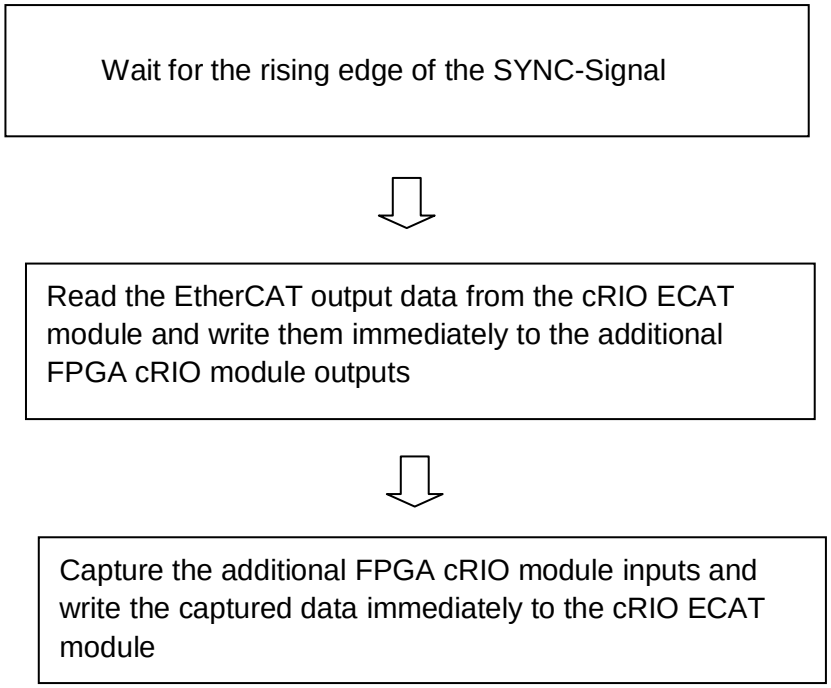


Figure 22: SYNC Parameter - Property node Cycle Time / Synced with DC

FPGA based EtherCAT synchronization application

The FPGA application uses SYNC Signal to synchronize the cRIO system input- and output data with the Network EtherCAT cycle:



See also the KUNBUS FPGA based example code in the LabVIEW example.

EtherCAT Slave Example

Location

The sample project can be found in the NI Example Finder:
LabVIEW -> Help -> Find Examples
Choose the directory
Toolkits and Modules -> Third-Party Add-Ons -> KUNBUS GmbH -> EtherCAT
Open the LabVIEW project *cRIO ECAT S Getting Started.lvproj*

You also can search for ECAT or KUNBUS to find the Getting Started project.

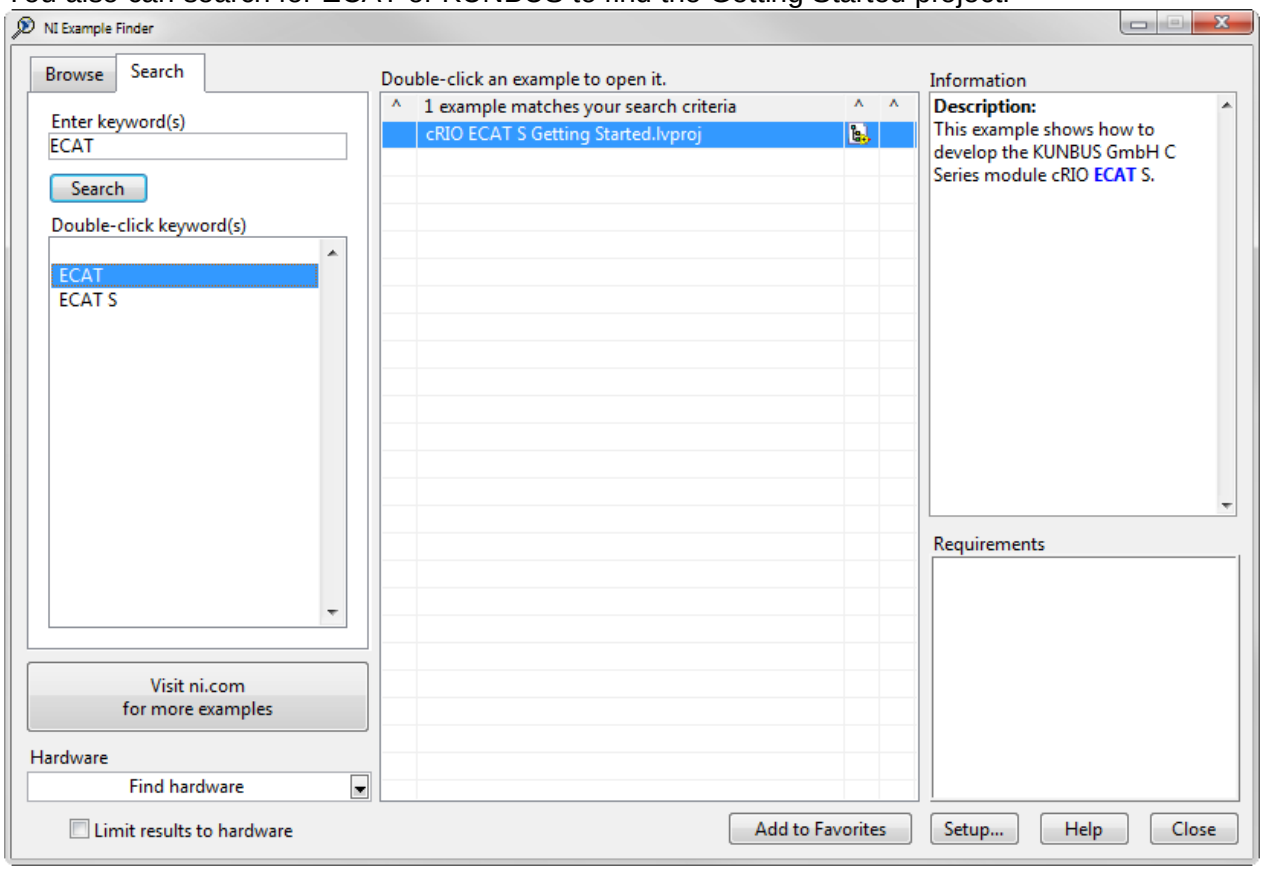


Figure 23: NI Example Finder

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