Application Note ET9300 (EtherCAT Slave Stack Code)

Version 1.8
Date: 2017-11-14

LEGAL NOTICE

DOCUMENT HISTORY

Version	Comment
1.0	Start document
1.1	Chapter 4 “Hardware access”. Define descriptions; prototypes changed
1.2	Add chapter 5 Application Add chapter 9 Tool Add chapter 9 TestApplication Enhance Hardware access (chapter 4) update name references Enhance EoE chapter
1.3	TestApplication; chapter9 :Update object/entry description (0x2020.1, 0x3003, 0x3004 and 0x3007) Update “HW_GetTimer()” description SSC Tool: Edit file information Update SSC Structure Add “Find Setting” dialog description Update naming in Object chapter
1.4	SSCTool: - Remove Wizard - Add Configuration handling
1.5	Editorial changes Add “Getting Started” chapter Add description for hardware adaption Test Application: - Add new test description - Enhance/update application description - Describe mechanism to control the behaviors Enhance Application chapter - Add setting description - Interface variables - Guide to create an application Add “Synchronization” chapter Hardware chapter: Sync1_Isr() description added Update SSC configuration references Add “EEPROM Handling” chapter - EEPORM Emulation - EEPROM Programming
1.6	Editorial changes Update object list of test application Update SSC Tool description (chapter 12) according version 1.3.1
1.7	Chapter 6.4.1 : Add offline object dictionary enhancement Add new mailbox test behaviors Indicate obsolete hardware functions Editorial changes Update SSC Tool screenshots and GUI description Add further test object in the test application Add object design rules Update references if TwinCAT 3 is used Add SSC OD Tool description Add optional EEPROM interface functions. Add Bootloader information
1.8	Update synchronization chapter (describe the timing measurement feature) Add an EtherCAT state machine chapter Add EoE application interface description Add Backup Parameter function list and function calls. Enhance FoE description and add FoE callback functions. Add examples how to define an application Add application parser CoE callback infos Update EEPROM emulation infos Testapplication : enhance object 0x3001 to test real and 64bit datatypes Add clause “Process Data” and “EtherCAT State Machine” Add clause Slave Identification

NOTE: This document makes no claim to be complete regarding to the containing topics or the Slave Stack Code. For annotations or comments to this document please send an email to EthercatSSC@beckhoff.com.

CONTENTS

FIGURES

TABLES

1 References

[1] ETG.6010 Implementation Guideline for the CiA402 Drive Profile (www.ethercat.org/ETG6010)
[2] ETG.1000 part 6 Application Layer protocol specification (www.ethercat.org/ETG1000)
[3] Application Note EL9800
[4] ETG.2000 Slave Information Specification (www.ethercat.org/ETG2000)
[5] ETG 5001 Modular Device Profile Specification (www.ethercat.org/ETG5001)
[6] ET1100 Datasheet
[7] ETG.1020 Protocol Enhancements (www.ethercat.org/ETG1020)
[8] EtherCAT Slave Quick Design Guide (http://download.beckhoff.com/download/Document/EtherCAT/Development_products/EtherCAT_Slave_Design_Quick_Guide.pdf)

2 Terms, Definition, Abbreviation

Base Datatypes -- CoE Datatypes defined in ETG.1000.6

Entry – in conclusion with object single element,

in conclusion with object dictionary the objects

Subindex -- describes a single element (entry) of an object

Object dictionary – the object dictionary is a list of objects. Within this list each object is uniquely identified by an (object) index.

2.1 Abbreviation

Abbreviation	Description
AL	Application Layer
CoE	CANopen application profile over EtherCAT CANopen™ is a registered trademark of CAN in Automation e.V., Nuremberg, Germany
CiA402	CANopen™ Drive Profile specified in IEC 61800-7-201; CANopen™ and CiA™ are registered trademarks of CAN in Automation e.V., Nuremberg, Germany
csp	cycle synchronous position
csv	cycle synchronous velocity
DC	Distributed Clocks
EoE	Ethernet over EtherCAT
ESC	EtherCAT Slave Controller
FoE	File Transfer over EtherCAT
GPO	General Purpose Output
NC	Numeric Control
PDI	Process data interface
PDO	Process Data Object
PLC	Programmable Logic Controller
SI	SubIndex
SII	Slave Information Interface
SM	Sync Manager
SPI	Serial Peripheral Interface
SSC	Slave Stack Code

3 Getting Started

This is a step by step instruction how to start the EtherCAT slave development with the Slave Stack Code (SSC).
There is also an EtherCAT Slave Design Quick Guide available in the downloaded SSC archive.
In general two possibilities are available either using the SSC Tool (3.1 SSC Tool) or the default SSC files (3.2 Default SSC files).

Further information regarding the SSC are also available in the ETG developers forum.

3.1 SSC Tool

1. Download the Slave Stack Code here.
   NOTE: To download the SSC the ETG member login and an EtherCAT Vendor ID is required. If you are not an ETG member click here or if you do not have an EtherCAT Vendor ID click here.
2. Unzip the downloaded archive.
3. Install "EtherCAT Slave Stack Code Tool.msi".
4. Start the SSC Tool (Start -> Program Files -> EtherCAT Slave Stack Code Tool -> SSC Tool).
5. Acknowledge the usage agreement.
6. Enter your Vendor ID and company name.
7. Create a new project (File -> New)
8. Select ...
   a. the default SSC configuration.
   b. a custom platform/application configuration. If a configuration file is available it can also be added via the "Import" button.

   NOTE: If the SSC shall be executed on a third party platform, e.g. Texas Instruments AM335x or Renesas R-IN32M3, it is recommended to use the corresponding configuration.
9. If the default SSC configuration was selected the hardware defines should be adapted according to the target platform (Project Navigation -> "Hardware").
10. Select the slave application (Project Navigation -> "Application").
11. Save the project (File -> Save).
12. If Doxygen is installed a source code documentation can be created automatically (Tool -> Options -> Create Files -> Create Documentation).
13. Create the slave files (Project -> Create new Slave Files).
14. Click "Start".
15. Create a slave project with the target platform specific IDE, import the generated source files and run the slave binary. For further details see the IDE/SDK documentation of the platform vendor.
16. Make the ESI file available in the ESI cache of the EtherCAT configuration tool/master.
17. Connect the slave platform and the EtherCAT configuration tool and create a network.
18. Run the network configuration.

3.2 Default SSC files

1. Download the Slave Stack Code here.
   NOTE: To download the SSC the ETG member login and an EtherCAT Vendor ID is required. If you are not an ETG member click here or if you do not have an EtherCAT Vendor ID click here.
2. Unzip the downloaded archive.
3. Create a slave project with the target platform specific IDE, import the SSC files and run the slave binary. For further details see the IDE/SDK documentation of the platform vendor.

4. Adapt the defines in ecat_def.h to the target platform and application.
5. Create an ESI file according to the defines in step 4.
6. Make the ESI file available in the ESI cache of the EtherCAT configuration tool/master.
7. Connect the slave platform and the EtherCAT configuration tool and create a network.
8. Run the network configuration.

4 Code Structure

The EtherCAT slave stack as seen in Figure 1 consists of three parts:

- PDI/Hardware abstraction
    - Hardware specific, need to be implemented according the platform/PDI
    - Ready to used samples/implementations are available for certain platforms
    - The interface to the generic stack is described in chapter 5.
- Generic EtherCAT stack
    - Implements the full EtherCAT statemachine, mailbox communication and generic process data exchange
    - No further implementation need (only configured via the SSC Tool, chapter 12 or defines)
- User application
    - Need to be implemented (a table-based code generator for the application is available, chapter 13.
    - Ready to uses samples are available
    - The interface to the generic stack is described in chapter 6.

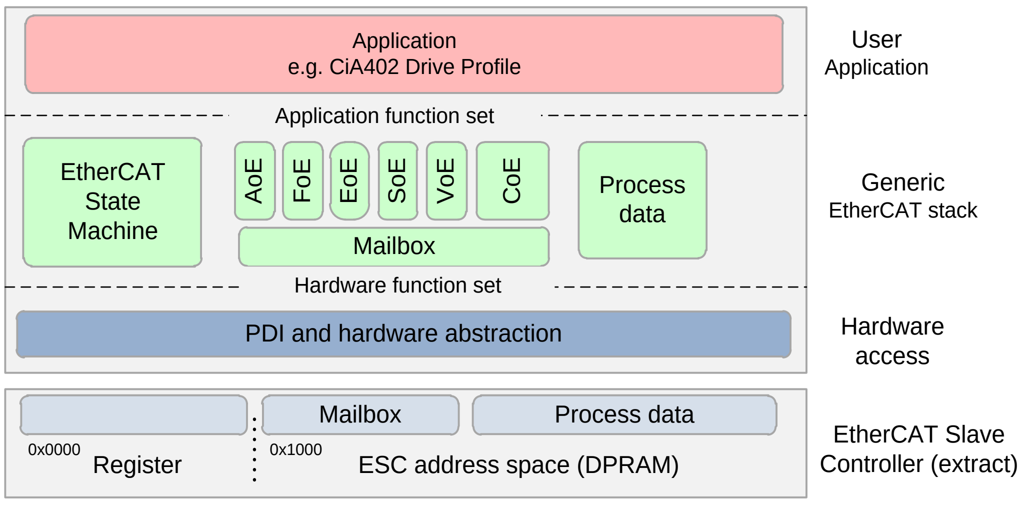


Figure 1: EtherCAT Slave Stack Code

Figure 2 shows the association between the Slave Stack Code layers and the source files.

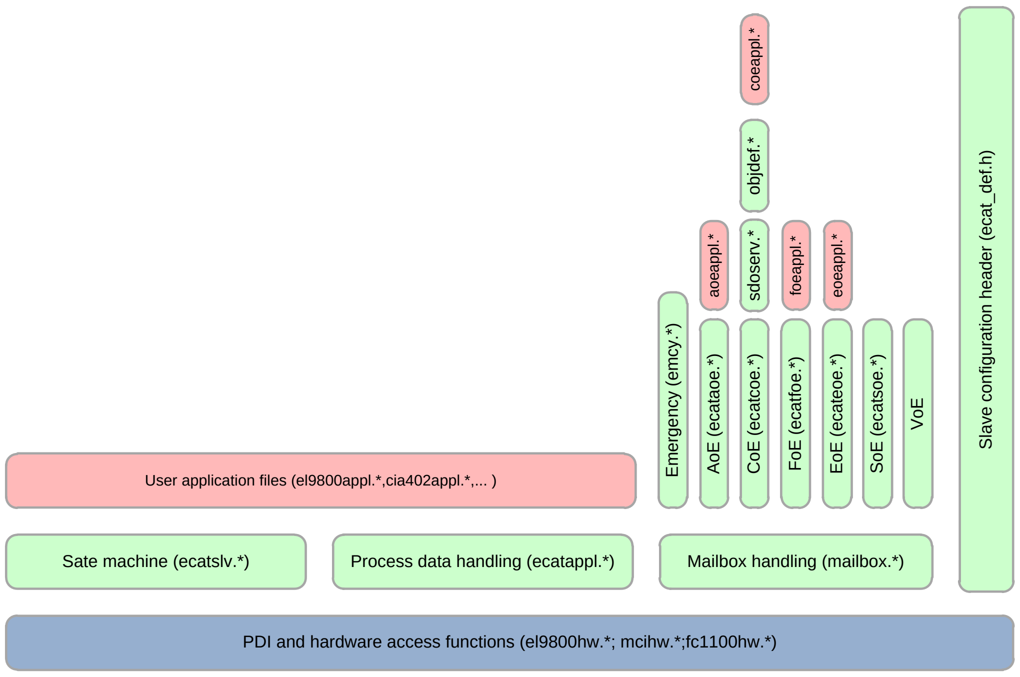
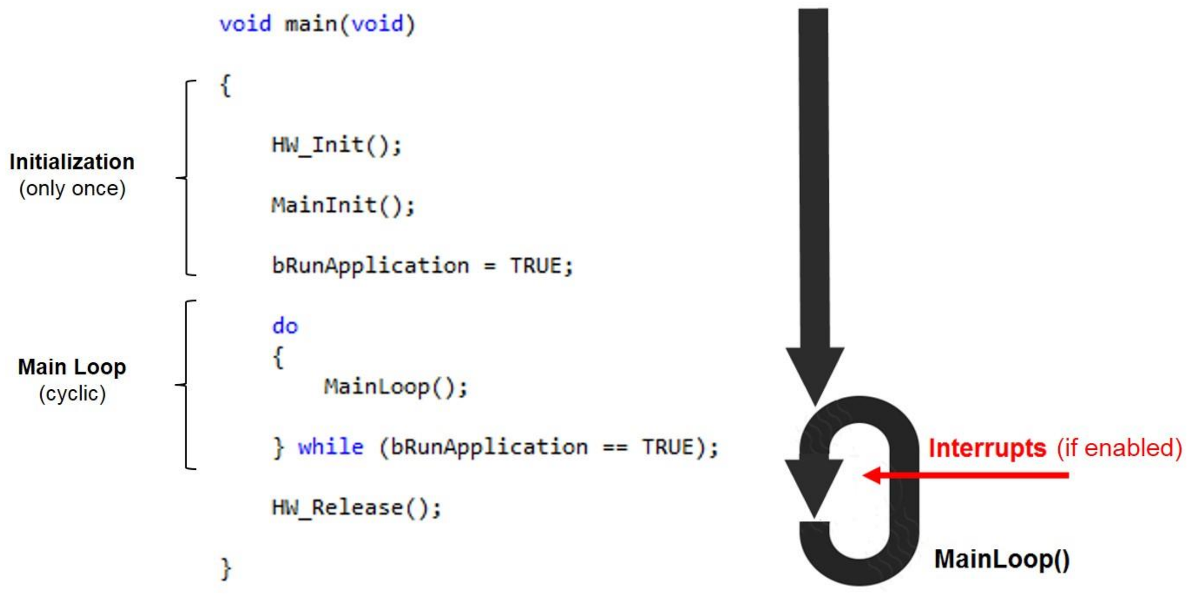

coeappl.*
objdef.*
aoeappl.*
sdoserv.*
foeappl.*
eoeappl.*
Emergency (emcy.*)
AoE (ecataoe.*)
CoE (ecatcoe.*)
FoE (ecatfoe.*)
EoE (ecateoe.*)
SoE (ecatsoe.*)
VoE
Slave configuration header (ecat_def.h)
User application files (el9800appl.*,cia402appl.*,...)
Sate machine (ecatslv.*)
Process data handling (ecatappl.*)
Mailbox handling (mailbox.*)
PDI and hardware access functions (el9800hw.*; mcihw.*;fc1100hw.*)

Figure 2: File-Stack Association

The structure of the code can be adapted to the application specific requirements by using the Slave Stack Code Tool (chapter 12).

4.1 Execution structure

The SSC execution consists of an initialization phase (executed only once) and a cyclic phase (executed continuously without interruptions).



```
void main(void)
{
    HW_Init();
    MainInit();
    bRunApplication = TRUE;
    do
    {
        MainLoop();
    } while (bRunApplication == TRUE);
    HW_Release();
}
```

Figure 3: Basic SSC execution structure

The function MainLoop() contains the main cycle of the Slave´s firmware, which always runs in free-run (unsynchronised endless loop):

MainLoop()   (file: ecatappl.c)

-	ECAT_Main()	(file: ecatslv.c)	
-	CoE_Main()	(file: coeappl.c)	
-	[PDO_OutputMapping()	(file:ecatappl.c)	only in Free-Run mode]

- [ECAT_Application() (file: ecatappl.c) only in Free-Run mode]
- [PDO_InputMapping() (file: ecatappl.c) only in Free-Run mode]

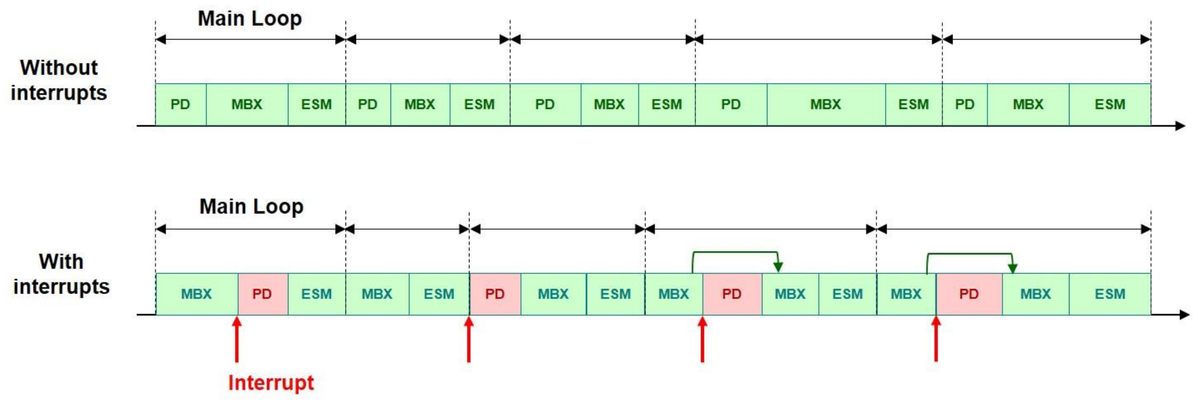


Figure 4: SSC MainLoop execution

4.2 Interrupt handling

The SSC makes use of up to four interrupts. The corresponding interrupt handler of the generic stack are listed in chapter 5.1.

1. Timer Interrupt : platform internal 1ms timer to set the EtherCAT LEDs and watchdogs. If no timer interrupt is configured (ECAT_TIMER_INT = 0) the required 1ms cycle is based on the mainloop an platform internal counter.
2. Sync0 : Process data handling and application synchronization with Distributed Clocks (DC), see chapter 9.
3. Sync1 : Process data handling and application synchronization with Distributed Clocks (DC), see chapter 9.
4. PDI Interrupt: Process data handling and application synchronization with, see chapter 9.

The events which trigger the PDI interrupt can be configured by the slave application (Figure 5).

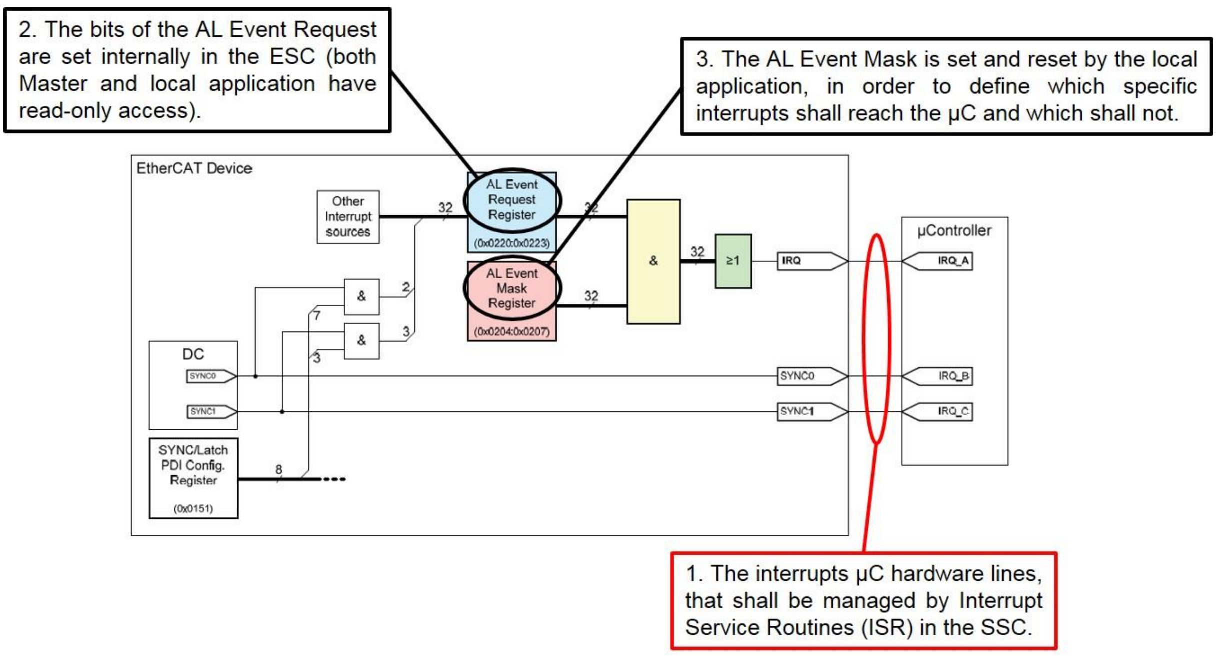

2. The bits of the AL Event Request are set internally in the ESC (both Master and local application have read-only access).
3. The AL Event Mask is set and reset by the local application, in order to define which specific interrupts shall reach the µC and which shall not.
EtherCAT Device
Other Interrupt sources
AL Event Request Register (0x0220:0x0223)
AL Event Mask Register (0x0204:0x0207)
&
≥1
IRQ
µController
IRQ_A
DC
SYNC0
SYNC1
IRQ_B
IRQ_C
SYNC/Latch PDI Config. Register (0x0151)
32
8
1. The interrupts µC hardware lines, that shall be managed by Interrupt Service Routines (ISR) in the SSC.

Figure 5: ESC Interrupts basics

The only interrupt sources which are actually handled by PDI ISR in the SSC, and therefore not filtered by the AL Event Mask, are the **Process Data SyncManager interrupts**, and specifically: SM2 if Process Data Outputs are configured for the Slave, otherwise SM3. All the other possible sources (included all other SyncManagers) can be directly polled in Register 0x0220.

The Interrupt mask is configured by the functions “SetALEventMask()” and “ResetALEventMask()” (file: ecatslv.c).

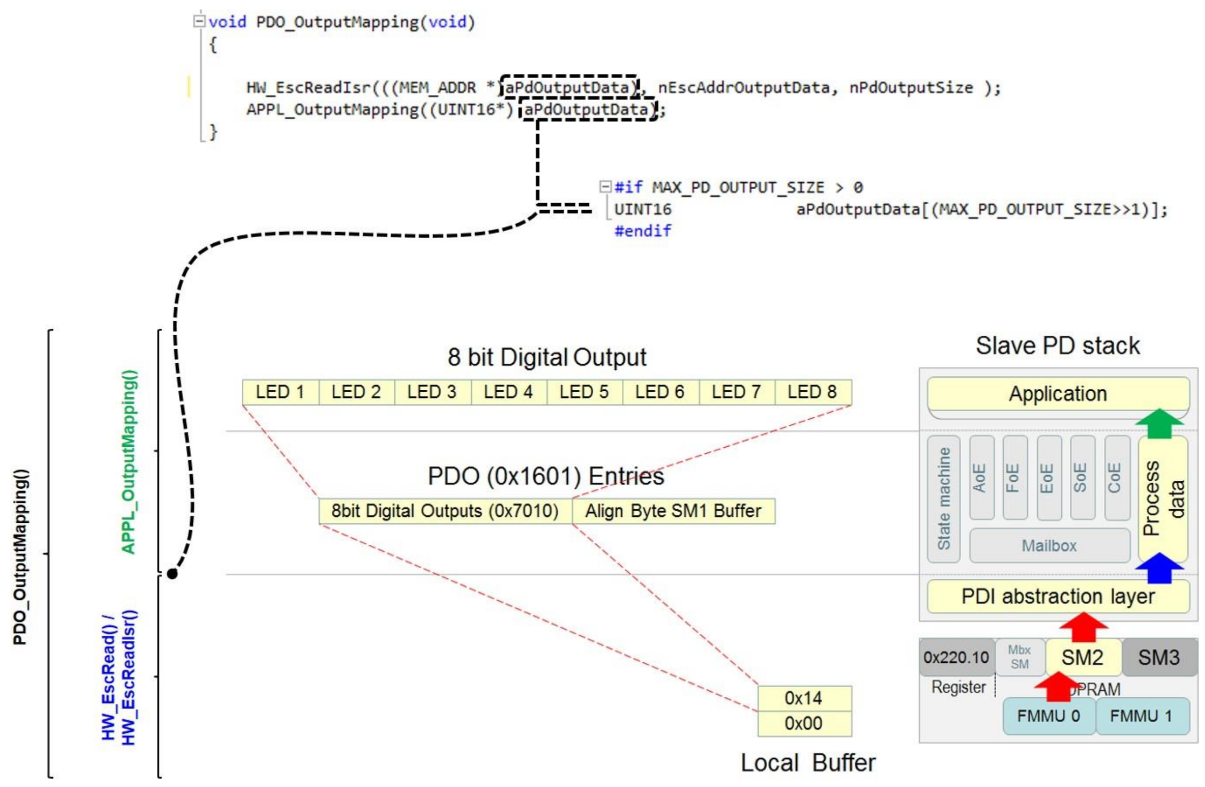
4.3 Process data handling

The EtherCAT slave process data communication can be separated in two steps. The first one is the low level on-the-fly data exchange. The ESC reads/writes data from/to the EtherCAT frame and stores/reads the data to the internal DPRAM.
In the second step the slave application will do further data processing/calculation, which is described in this chapter.

The process data handling in the SSC is managed in three functions of the generic stack. Each of these functions triggers the corresponding application specific functions (chapter 6.2.3).

1. PDO_OutputMapping() : handles the data from the master to the slave, e.g. EL9800 application, Figure 6.
2. ECAT_Application() : contains the slave application, e.g. EL9800 application, set digital outputs, read digital inputs, read the analog digital converted value.
3. PDO_InputMapping() : handles the data from the slave to the master, e.g. EL9800 application, Figure 7)

The calling sequence of the three listed functions is always the same (the one listed above). The function trigger depends on the configured synchronisation mode (see 9 for further details).

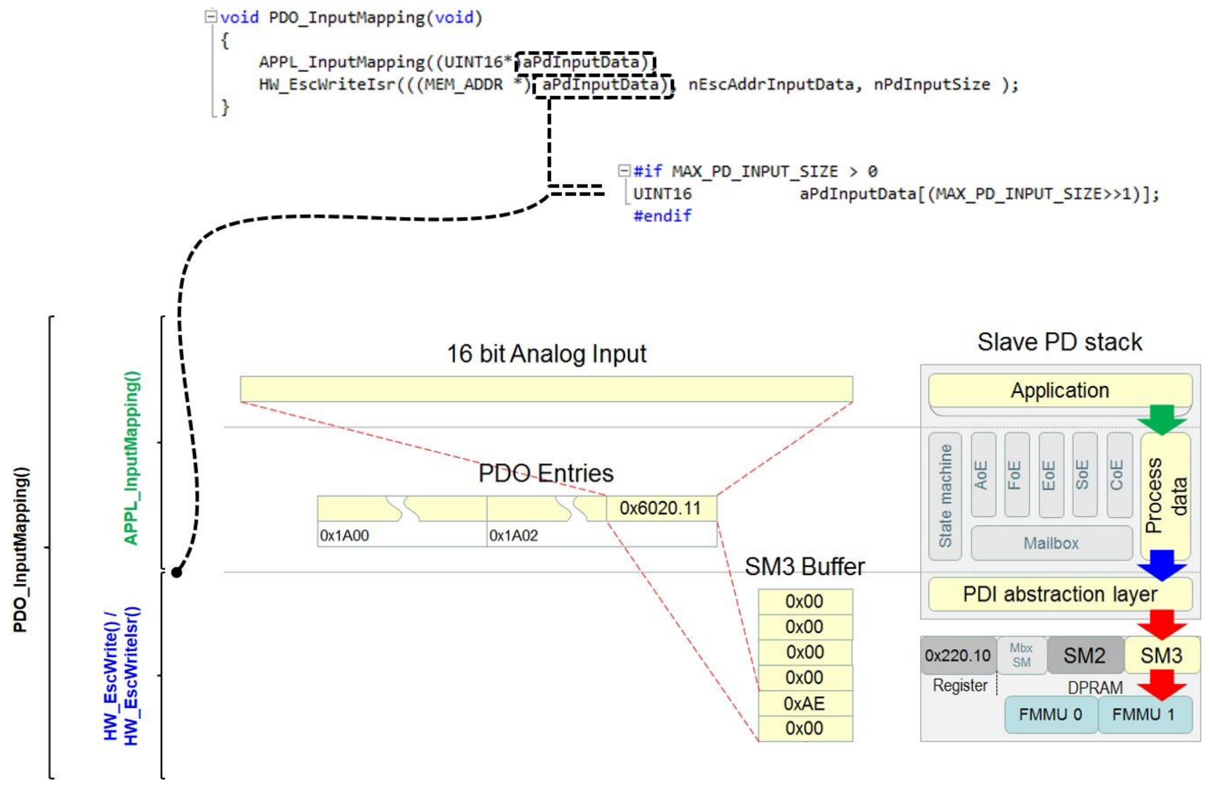


```
void PDO_OutputMapping(void)
{

    HW_EscReadIsr(((MEM_ADDR *) aPdOutputData), nEscAddrOutputData, nPdOutputSize );
    APPL_OutputMapping((UINT16*) aPdOutputData);
}
```

```
#if MAX_PD_OUTPUT_SIZE > 0
UINT16              aPdOutputData[(MAX_PD_OUTPUT_SIZE>>1)];
#endif
```

Figure 6: EL9800 Application Output Mapping



```
void PDO_InputMapping(void)
{
    APPL_InputMapping((UINT16*)aPdInputData);
    HW_EscWriteIsr(((MEM_ADDR *) aPdInputData), nEscAddrInputData, nPdInputSize );
}
```

```
#if MAX_PD_INPUT_SIZE > 0
UINT16            aPdInputData[(MAX_PD_INPUT_SIZE>>1)];
#endif
```

Figure 7: EL9800 Application Input Mapping

5 Hardware Access

The Slave Stack Code is executable on multiple platforms and controller architectures. This chapter describes the available hardware implementations/defines and how to implement a new user specific hardware access.
To support multiple hardware architectures the SSC includes multiple defines to fulfill the specific hardware requirements. Table 1: Hardware Related includes a list of the defined hardware defines (located in ecat_def.h or in the SSC Tool).

Table 1: Hardware Related Defines

Define	Description
EL9800_HW	Hardware access if the slave code is executed on the PIC mounted on EL9800 EtherCAT Evaluation Kit from Beckhoff Automation GmbH. It includes PIC initialization and ESC access via SPI. This configuration could also be used if the SSC needs to be adapted to any other 8 or 16Bit µC which accesses the ESC via SPI.
PIC24	Activates the configuration for the Microchip PCI24HJ128GP306 µC which is mounted on the EL9800 EtherCAT Evaluation board since Revision 4A. This define shall only active if define “EL9800_HW” is also set.
PIC18	Activates the configuration for the Microchip PIC18F452 µC which is mounted on the EL9800 EtherCAT Evaluation board, Revision 2. This define shall only active if define “EL9800_HW” is also set.
MCI_HW	Generic MCI implementation. Can be used if any kind of memory interface face is used to access the ESC.
FC1100_HW	Specific hardware implementation for the FC1100 PCI EtherCAT slave card from Beckhoff. Used on Win32 operating system.
CONTROLLER_16BIT	This define shall be used if the slave code is built for a 16Bit µC.
CONTROLLER_32BIT	This define shall be used if the slave code is built for a 32Bit µC.
ESC_16BIT_ACCESS	If this define is set, then only 16Bit aligned accesses will be performed on the ESC.
ESC_32BIT_ACCESS	If this define is set, then only 32Bit aligned accesses will be performed on the ESC.
MBX_16BIT_ACCESS	If this define is set, then the slave code will only access mailbox data 16Bit aligned. If the mailbox data is copied to the local µC memory and the define “CONTROLLER_16BIT” is set, then this define should also be set.
BIG_ENDIAN_16BIT	These define needs to be set if the µC always accesses external memory 16Bit wise. It works in big endian format and the switching of Low Byte and High Byte is done in hardware.
BIG_ENDIAN_FORMAT	This define shall be set if the µC works in big endian format.

The defines “EL9800_HW”, “PIC24”, “PIC18”, MCI_HW”, “FC1100_HW” are used to activate a predefined hardware access implementation. An extract of platforms/ µC is listed in Table 2: Recommended Hardware Configurations including the recommended defines. Some of the configurations can also be selected if a new project is created with the SSC Tool (see comment). If none of these defines are used, then user specific hardware access files need to be added to the

slave project.
In general the hardware access implementation needs to support the following features:

- ESC read/write access
- Timer supply (at least 1ms base tick)
- Calling of timer handler every 1ms (only required if timer interrupt handling is supported ,“ECAT_TIMER_INT” set to 1)
- Calling the interrupt specific functions (only required if synchronization is supported)
    - PDI ISR (required if “AL_EVENT_SUPPORTED” set to 1)
    - SYNC0 ISR (required if “DC_SUPPORTED” set to 1)

Table 2: Recommended Hardware Configurations

Platform	EL9800_HW	PIC24	PIC18	MCI_HW	FC1100_HW	CONTROLLER_16BIT	CONTROLLER_32BIT	ESC_16BIT_ACCESS	ESC_32BIT_ACCESS	MBX_16BIT_ACCESS	BIG_ENDIAN_16BIT	BIG_ENDIAN_FORMAT	Comment
Microchip PIC18F452 Generic : 8Bit µC ; SPI ESC access	1	0	1	0	0	0	0	0	0	0	0	0	The stack is ready to use if the PIC 18 on the EL9800 EtherCAT Evaluation board is used. Otherwise there might be requirements to adapt the hardware access
Microchip PIC24HJ128GP306 Generic: 16Bit µC; SPI ESC access	1	1	0	0	0	1	0	1	0	1	0	0	The stack is ready to use if the PIC 24 on the EL9800 EtherCAT Evaluation board is used. Otherwise there might be requirements to adapt the hardware access.
x86 (OS Windows)	0	0	0	0	1	0	1	0	1	0	0	0	The stack is ready to use if the stack shall run on a Win32 OS in user mode. Otherwise changes in hardware access might be required. The define "FC1100_HW" is a adapted implementation based on "MCI_HW
Texas Instruments Sitara AM335x	0	0	0	0	0	0	0	0	0	0	0	0	To use the SSC on TI AM335x chips the hardware access files from the TI SDK need to be added to the project. The files can be added to the slave project via the patch file (delivered with the SDK), by selecting the TI configuration in the SSC Tool or by adding the files manually.
Altera® NIOS®II (ESC connected via Avalon bus)	0	0	0	1	0	x	x	x	x	x	0	0	x: depends on the NIOS® configuration in the SOPC builder. In general the following points need to be adapted: - define "MAKE_PTR_TO_ESC" - ISRs for Timer/PDI interrupt and Sync0 (depends on the supported features) - Implement timer access functions and macros Depending on the platform configuration further changes may be required.

Platform	EL9800_HW	PIC24	PIC18	MCI_HW	FC1100_HW	CONTROLLER_16BIT	CONTROLLER_32BIT	ESC_16BIT_ACCESS	ESC_32BIT_ACCESS	MBX_16BIT_ACCESS	BIG_ENDIAN_16BIT	BIG_ENDIAN_FORMAT	Comment
Xilinx Microblaze™ (ESC connected via PLB)	0	0	0	1	0	x	x	x	x	x	x	0	x: depends on the Microblaze™ configuration. In general the following points need to be adapted: - define “MAKE_PTR_TO_ESC” - ISRs for Timer/PDI interrupt and Sync0 (depends on the supported features) - Implement timer access functions and macros Depending on the platform configuration further changes may be required.
Renesas - RIN32M3	0	0	0	0	0	0	0	0	0	0	0	0	To use the SSC on Renesas RIN32M3 chip the chip specific hardware access files need to be added to the project. The files are added automatically if the Renesas PIN32M3 configuration is selected in the SSC Tool.
Xilinx ZYNQ™ (ESC connected via the on-chip bus)	0	0	0	1	0	x	x	x	x	x	0	0	x: depends on the ZYNQ™ configuration. In general the following points need to be adapted: - define “MAKE_PTR_TO_ESC” - ISRs for Timer/PDI interrupt and Sync0 (depends on the supported features) - Implement timer access functions and macros Depending on the platform configuration further changes may be required.

The following two chapters describe the functions which shall be called and provided by the hardware access layer (Figure 8).

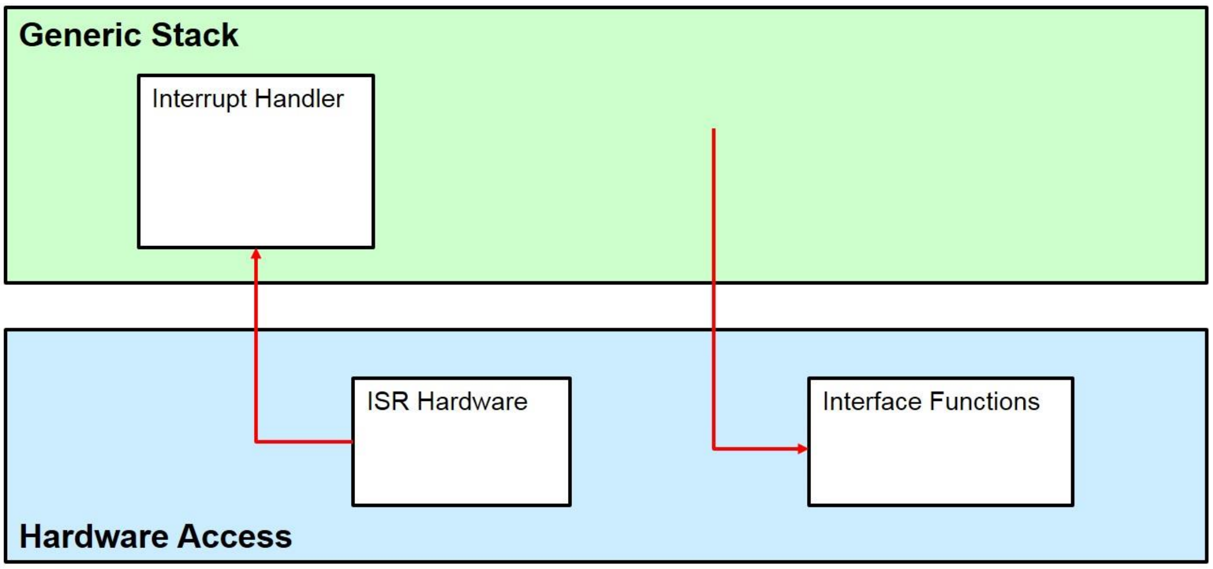


Figure 8: Hardware Functions Schema

- Interrupt Handler: functions completely defined and implemented in the generic EtherCAT stack, shall be called by the hardware interrupt routines of the specific µC. (chapter 5.1)

If interrupts are used also two macros shall be defined "ENABLE_ESC_INT" and "DISABLE_ESC_INT". These shall enable/disable all four interrupt sources.

- Interface Functions/Macros: functions called by the generic EtherCAT stack, shall be implemented in the hardware access code. (chapter 0)

5.1 Interrupt Handler

The following functions are provided by the generic Slave Stack Code (defined in ecatappl.h) and need to be called from the hardware access layer.

Prototype:	**void ECAT_CheckTimer (void)**
Parameter	void
Return	void
Description	This function needs to be called every 1ms from a timer ISR (ECAT_TIMER_INT = 1). If no timer interrupt is supported this function is called automatically when 1ms is elapsed (based on the provided timer).

Prototype:	**void PDI_Isr (void)**
Parameter	void
Return	void
Description	This function need to be called from the PDI ISR. For the PDI specific pin naming and the interrupt generation logic please refer to [6] . To support PDI interrupt handling it is also required to set "AL_EVENT_ENABLED" to 1.

Prototype:	**void Sync0_Isr (void)**
Parameter	void
Return	void
Description	This function needs to be called from the Sync0 ISR. The Sync0 interrupt is generated by the DC Unit of the ESC. It is currently not supported by default to map the Sync0 signal to the PDI interrupt. To support Dc synchronization “DC_SUPPORTED” need to be set.

Prototype:	**void Sync1_Isr (void)**
Parameter	void
Return	void
Description	This function needs to be called from the Sync1 ISR. The Sync1 interrupt is generated by the DC Unit of the ESC. It is currently not supported by default to map the Sync1 signal to the PDI interrupt. To support Dc synchronization “DC_SUPPORTED” need to be set.

If interrupts are used also two macros shall be defined “ENABLE_ESC_INT” and “DISABLE_ESC_INT”. These shall enable/disable all four interrupt sources.

5.2 Interface Functions/Macros

The functions and macros listed in this chapter need to be implemented by the hardware access layer.

5.2.1 Generic

Prototype:	**UINT16 HW_Init(void)**
Parameter	void
Return	0 if initialization was successful > 0 if error has occurred while initialization
Description	Initializes the host controller, process data interface (PDI) and allocates resources which are required for hardware access.

Prototype:	**void HW_Release(void)**
Parameter	void
Return	void
Description	Release allocated resources.

Prototype:	**UINT16 HW_GetALEventRegister(void)**	
Parameter	void	
Return	Content of register 0x220-0x221	
Description	Get the first two bytes of the AL Event register (0x220-0x221).	

Prototype:	**UINT16 HW_GetALEventRegister_Isr(void)**	
Parameter	void	
Return	Content of register 0x220-0x221	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as HW_GetALEventRegister. Get the first two bytes of the AL Event register (0x220-0x221).	

Prototype:	**void HW_ResetALEventMask(UINT16 intMask)**	
Parameter	“intMask”	Interrupt mask (disabled interrupt shall be zero)
Return	void	
Description	Performs a logical AND with the AL Event Mask register (0x0204 : 0x0205). This function is only required if “AL_EVENT_ENABLED” is set. NOTE: This function is only required for SSC 5.10 or older.	

Prototype:	**void HW_SetALEventMask(UINT16 intMask)**	
Parameter	“intMask”	Interrupt mask (enabled interrupt shall be one)
Return	void	
Description	Performs a logical OR with the AL Event Mask register (0x0204 : 0x0205). This function is only required if “AL_EVENT_ENABLED” is set. NOTE: This function is only required for SSC 5.10 or older.	

Prototype:	**void HW_SetLed(UINT8 RunLed,UINT8 ErrLed)**	
Parameter	“RunLed”	EtherCAT Run LED state
	“ErrLed”	EtherCAT Error LED state
Return	void	
Description	Updates the EtherCAT Run and Error LEDs (or EtherCAT Status LED).	

Prototype:	**void HW_RestartTarget(void)**
Parameter	void
Return	void
Description	Resets the hardware. This function is only required if "BOOTSTRAPMODE_SUPPORTED" is set.

Prototype:	**void HW_DisableSyncManChannel(UINT8 channel)**	
Parameter	"channel"	SyncManager channel
Return	void	
Description	Disables selected SyncManager channel. Sets bit 0 of the corresponding 0x807 register. NOTE: This function is only required for SSC 5.10 or older.	

Prototype:	**void HW_EnableSyncManChannel (UINT8 channel)**	
Parameter	"channel"	SyncManager channel
Return	void	
Description	Enables selected SyncManager channel. Resets bit 0 of the corresponding 0x807 register. NOTE: This function is only required for SSC 5.10 or older.	

Prototype:	**TSYNCMAN * HW_GetSyncMan(UINT8 channel)**	
Parameter	"channel"	SyncManager channel
Return	Pointer to the SyncManager channel description. The SyncManager description structure size is always 8 Byte, the content of "TSYNCMAN" differs depending on the supported ESC access.	
Description	Gets the content of the SyncManager register from the stated channel. Reads 8 Bytes starting at 0x800 + 8*channel. NOTE: This function is only required for SSC 5.10 or older.	

Prototype:	**UINT32 HW_GetTimer(void)**
Parameter	void
Return	Current timer value
Description	Reads the current register value of the hardware timer. If no hardware timer is available the function shall return the counter value of a multimedia timer. The timer ticks value (increments / ms) is defined in “ECAT_TIMER_INC_P_MS”. This function is required if no timer interrupt is supported (“ECAT_TIMER_INT” = 0) and to calculate the bus cycle time.

Prototype:	**void HW_ClearTimer(void)**
Parameter	void
Return	void
Description	Clears the hardware timer value.

Prototype:	**UINT16 HW_EepromReload (void)**
Parameter	void
Return	0 <> Error during EEPORM reload 0 = EEPROM load correct
Description	This function is called if an EEPROM reload request is triggered by the master. Only required if EEPROM Emulation is supported and the function pointer “pAPPL_EEPROM_Reload” is not set. In case that the full eeprom emulation is configured (register 0x502, bit6 is 1) the reload function is not called and does not to be implemented.

5.2.2 Read Access

Prototype:	**void HW_EscRead(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	“pData”	Pointer to local destination buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	“Len”	Access size in Bytes
Return	void	
Description	Reads from the EtherCAT Slave Controller. This function is used to access ESC registers and the DPRAM area.	

Prototype:	**void HW_EscReadIsr(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	“pData”	Pointer to local destination buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	“Len”	Access size in Bytes
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as “HW_EscRead”. Reads from the EtherCAT Slave Controller. This function is used to access ESC registers and the DPRAM area.	

Prototype:	**void HW_EscReadDWord(UINT32 DWordValue, UINT16 Address)**	
Parameter	“DWordValue”	Local 32Bit variable where the register value shall be stored.
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 32Bit addresses are used.
Return	void	
Description	Reads two words from the specified address of the EtherCAT Slave Controller. In case that no specific read DWORD marco is used the default EscRead function may be used: “HW_EscRead(((MEM_ADDR *)&(DWordValue)),((UINT16)(Address)),4)”	

Prototype:	**void HW_EscReadDWordIsr(UINT32 DWordValue, UINT16 Address)**	
Parameter	“DWordValue”	Local 32Bit variable where the register value shall be stored.
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 32Bit addresses are used.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as “HW_EscReadWord”. Reads two words from the specified address of the EtherCAT Slave Controller.	

Prototype:	**void HW_EscReadWord(UINT16 WordValue, UINT16 Address)**	
Parameter	"WordValue"	Local 16Bit variable where the register value shall be stored.
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 16Bit addresses are used.
Return	void	
Description	Reads one word from the specified address of the EtherCAT Slave Controller. Only required if "ESC_32BIT_ACCESS" is not set. In case that no specific read WORD marco is used the default EscRead function may be used: "HW_EscRead(((MEM_ADDR *)&(WordValue)),((UINT16)(Address)),2)"	

Prototype:	**void HW_EscReadWordIsr(UINT16 WordValue, UINT16 Address)**	
Parameter	"WordValue"	Local 16Bit variable where the register value shall be stored.
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 16Bit addresses are used.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as "HW_EscReadWord". Reads one word from the specified address of the EtherCAT Slave Controller. Only required if "ESC_32_BIT_ACCESS" is not set.	

Prototype:	**void HW_EscReadByte(UINT8 ByteValue, UINT16 Address)**	
Parameter	"ByteValue"	Local 8Bit variable where the register value shall be stored.
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes.
Return	void	
Description	Reads one byte from the EtherCAT Slave Controller. Only required if "ESC_16BIT_ACCESS" and "ESC_32BIT_ACCESS" are not set.	

Prototype:	**void HW_EscReadByteIsr(UINT8 ByteValue, UINT16 Address)**	
Parameter	“ByteValue”	Local 8Bit variable where the register value shall be stored.
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as “HW_EscReadByte”. Reads one byte from the EtherCAT Slave Controller. Only required if “ESC_16BIT_ACCESS” and “ESC_32BIT_ACCESS” are not set.	

Prototype:	**void HW_EscReadMbxMem(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	“pData”	Pointer to local destination mailbox buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	“Len”	Access size in Bytes
Return	void	
Description	Reads data from the ESC and copies to slave mailbox memory. If the local mailbox memory is also located in the application memory this function is equal to “HW_EscRead”.	

5.2.3 Write Access

Prototype:	**void HW_EscWrite(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	“pData”	Pointer to local source buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	“Len”	Access size in Bytes
Return	void	
Description	Writes from the EtherCAT Slave Controller. This function is used to access ESC registers and the DPRAM area.	

Prototype:	**void HW_EscWriteIsr(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	“pData”	Pointer to local source buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	“Len”	Access size in Bytes
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as “HW_EscWrite”. Writes from the EtherCAT Slave Controller. This function is used to access ESC registers and the DPRAM area.	

Prototype:	**void HW_EscWriteDWord(UINT32 DWordValue, UINT16 Address)**	
Parameter	“DWordValue”	Local 32Bit variable which contains the data to be written to the ESC memory area.
	“Address”	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 32Bit addresses are used.
Return	void	
Description	Writes one word to the EtherCAT Slave Controller.	

Prototype:	**void HW_EscWriteDWordIsr(UINT32 DWordValue, UINT16 Address)**	
Parameter	"DWordValue"	Local 32Bit variable which contains the data to be written to the ESC memory area.
	"Address"	EtherCAT Slave Controller address . Specifies the offset within the ESC memory area in Bytes. Only valid 32Bit addresses are used.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as "HW_EscWriteWord". Writes two words to the EtherCAT Slave Controller.	

Prototype:	**void HW_EscWriteWord(UINT16 WordValue, UINT16 Address)**	
Parameter	"WordValue"	Local 16Bit variable which contains the data to be written to the ESC memory area.
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 16Bit addresses are used.
Return	void	
Description	Writes one word to the EtherCAT Slave Controller. Only required if "ESC_32BIT_ACCESS" is not set.	

Prototype:	**void HW_EscWriteWordIsr(UINT16 WordValue, UINT16 Address)**	
Parameter	"WordValue"	Local 16Bit variable which contains the data to be written to the ESC memory area.
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid 16Bit addresses are used.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as "HW_EscWriteWord". Writes one word to the EtherCAT Slave Controller. Only required if "ESC_32BIT_ACCESS" is not set.	

Prototype:	**void HW_EscWriteByte (UINT8 ByteValue, UINT16 Address)**	
Parameter	"ByteValue"	Local 8Bit variable which contains the data to be written to the ESC memory area.

	"Address"	EtherCAT Slave Controller address.Specifies the offset within the ESC memory area in Bytes.
Return	void	
Description	Writes one byte to the EtherCAT Slave Controller. Only defined if "ESC_16BIT_ACCESS" and "ESC_32BIT_ACCESS" are disabled.	

Prototype:	**void HW_EscWriteByteIsr(UINT8 ByteValue, UINT16 Address)**	
Parameter	"ByteValue"	Local 8Bit variable which contains the data to be written to the ESC memory area
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes.
Return	void	
Description	This function should be implemented if a special function for ESC access from interrupt service routines is required; otherwise this function is defined as "HW_EscWriteByte". Writes one byte to the EtherCAT Slave Controller. Only defined if "ESC_16BIT_ACCESS" and "ESC_32BIT_ACCESS" are disabled.	

Prototype:	**void HW_EscWriteMbxMem(MEM_ADDR *pData, UINT16 Address, UINT16 Len)**	
Parameter	"pData"	Pointer to local source mailbox buffer. Type of the pointer depends on the host controller architecture (specified in ecat_def.h or the SSC Tool).
	"Address"	EtherCAT Slave Controller address. Specifies the offset within the ESC memory area in Bytes. Only valid addresses are used depending on 8Bit/16Bit or 32 Bit ESC access (specified in ecat_def.h or the SSC Tool).
	"Len"	Access size in Bytes.
Return	void	
Description	Writes data from the slave mailbox memory to ESC memory. If the local mailbox memory is also located in the application memory this function is equal to "HW_EscWrite".	

6 Application

This chapter includes an overview over the default (sample) applications, the application interface and a guideline how to start the own application development. Figure 9 shows the application function calling behavior.

The SSC contains a list of (sample) applications which can be used for master/slave testing or as basis for the application development. The corresponding defines are listed in Table 3: Application Related (located in ecat_def.h or in the SSC Tool).

Table 3: Application Related Defines

Define	Description
TEST_APPLICATION	This application supports almost all SSC features. Furthermore it is possible to force specific application behavior (see chapter 9). NOTE: this application shall not be used as basis for the application development.
EL9800_APPLICATION	Application based on the EL9800 EtherCAT Evaluation Board. 8(4) LEDs: 8(4) switches; 16Bit analog input
CiA402_DEVICE	Sample Implementation for the CiA402 Drive Profile. This application supports 2 modular Axis. See chapter 8 for further information.
SAMPLE_APPLICATION	Hardware independent application. Recommend application is if no SSC Tool configuration is available for the target platform.
SAMPLE_APPLICATION_INTERFACE	Sample application for Win32 to create a dynamic link library.

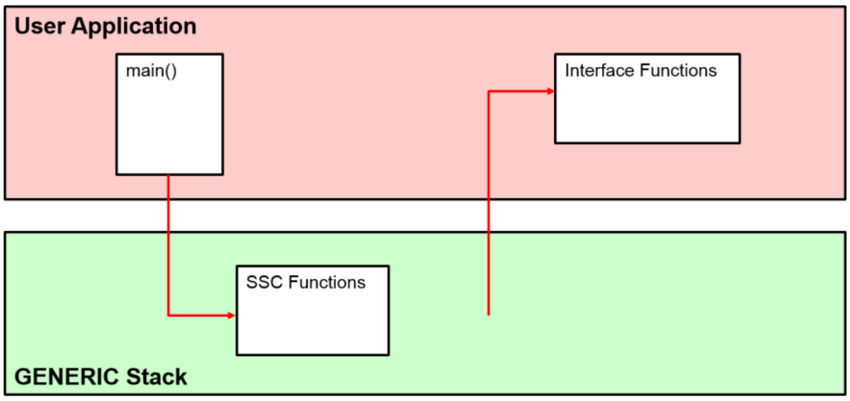


Figure 9: Application Functions Schema

- SSC Functions: functions completely defined and implemented in the generic EtherCAT stack, shall be called by the main() function of the user application code in order to trigger the generic stack. (chapter 6.1)
- Interface Functions: functions called by the generic EtherCAT stack, shall be implemented in the user application code. (chapter 6.2)

6.1 SSC Functions

These functions are provided by the generic stack and shall be called from the application layer. The functions are declared in the header “applInterface.h”.

Prototype:	**UINT16 MainInit(void)**
Parameter	Void
Return	0 if initialization was successful > 0 if error has occurred while initialization
Description	Initialize the generic slave stack. This function should be called after the platform including operating system and ESC is ready to use.

Prototype:	**void MainLoop(void)**
Parameter	Void
Return	Void
Description	This function handles the low priority function like EtherCAT state machine handling, mailbox protocols and if no synchronization is enabled also the application. This function shall be called cyclically from the application.

Prototype:	**void ECAT_StateChange(UINT8 alStatus, UINT16 alStatusCode)**	
Parameter	alStatus	Requested Al Status
	alStatusCode	AL Status Code. (if != 0 the error flag indication will be set)
Return	Void	
Description	This function shall be called by the application to trigger state transition in case of an application error or to complete a pending transition. If the function was called due to an error it shall be again if the error is gone. NOTE: state requests to a higher state than the current state are not allowed.	

Prototype:	**UINT16 EOE_SendFrameRequest(UINT16 *pData, UINT16 length)**	
Parameter	pData length	pointer to the frame to be send length of the frame to be send
Return	UINT16 retried later	0 if the frame sending started, 1 if the frame sending has to be
Description	This function sends an Ethernet frame via EoE to the master. The frame buffer shall dynamic allocated memory which will be deallocated by the SSC after the last EOE segment was send. Received frames are forwarded to “pAPPL_EoeReceive()” (chapter 6.2.4).	

6.2 Interface Functions

6.2.1 Generic

Prototype:	**void APPL_Application(void)**
Parameter	Void
Return	void
Description	This function is called by the synchronization ISR or from the mainloop if not synchronization is activated.

Prototype:	**UINT16 APPL_GetDeviceID (void)**
Parameter	Void
Return	Explicit Device ID which is written to the AL Status Code register.
Description	This function is called if the master requests the Explicit Device ID. Only required if the slave supports Explicit Device ID handling (EXPLICIT_DEVICE_ID).

Prototype:	**UINT16 (* pAPPL_EEPROM_Read)(UINT32 wordaddr)**
Parameter	Wordaddr start word address within the EEPROM memory
Return	0 if the operation was successful. greater 0 an error has occurred
Description	This is an optional function and only required if EEPROM_EMULATION is enabled and no EEPROM content is created (CREATE_EEPROM_CONTENT == 0) This function shall copy EEPROM data to the ESC EEPROM data register (0x508:0x50F/0x50B). The EEPROM data starting at the specified word address and the length specified with "EEPROM_READ_SIZE". The data shall be copied to the ESC EEPROM buffer (ESC offset 0x508) This function pointer will be reset in MainInit().

Prototype:	**UINT16 (* pAPPL_EEPROM_Write)(UINT32 wordaddr)**
Parameter	Wordaddr start word address within the EEPROM memory
Return	0 if the operation was successful. greater 0 an error has occurred
Description	This is an optional function and only required if EEPROM_EMULATION is enabled and no EEPROM content is created (CREATE_EEPROM_CONTENT == 0) This function shall copy data from the ESC EEPROM data register (0x508:0x50F/0x50B) to the EEPROM memory. The EEPROM data starting at the specified word address and the length specified with "EEPROM_WRITE_SIZE". This function pointer will be reset in MainInit().

Prototype:	**UINT16 (* pAPPL_EEPROM_Reload)(void)**
Parameter	Void
Return	0 if the operation was successful. greater 0 an error has occurred
Description	This is an optional function and only required if EEPROM_EMULATION is enabled and no EEPROM content is created (CREATE_EEPROM_CONTENT == 0). In case that this function is implemented the function “HW_EepromReload()” is not used. This function shall copy the EEPROM reload information to the ESC EEPROM data register (0x508:0x50F/0x50B). Read the ESC data sheet for the reload information (e.g. Beckhoff IPCore ESC Datasheet section II, chapter 3.45.1). This function pointer will be reset in MainInit().

Prototype:	**void (* pAPPL_EEPROM_Store)(void)**
Parameter	void
Return	void
Description	If EEPROM Emulation is enabled and the written data is not stored directly during the EEPROM Write commands to the permanent memory this function can be used to store the EEPROM data. It is called 1000 ms after the last EEPROM access. Using this function shall only be used if it is not possible to store the EEPROM data directly during the EEPROM write access. This function pointer will be reset in MainInit().

Prototype:	**void (*pAPPL_MainLoop)(void)**
Parameter	void
Return	void
Description	Called from the mainloop and may be used for non process data operations This function pointer will be reset in MainInit().

6.2.2 EtherCAT State Machine

Each ESM function returns a 16Bit Value which reflects the result of the state transition.
Return value:

0	Indicates a successful transition. Define : *ALSTATUSCODE_NOERRO*
0xFF	Indicates a pending state transition (the application need to complete the transition by calling ECAT_StateChange). Define : NOERROR_INWORK
Other	Indicates the reason for the failed transition. See [2] for a list of valid return codes.

Prototype:	**UINT16 APPL_StartMailboxHandler(void)**
Parameter	Void
Return	See generic ESM return code description
Description	This function is called during the state transition from INIT to PREOP or INIT to BOOT.

Prototype:	**UINT16 APPL_StopMailboxHandler(void)**
Parameter	Void
Return	See generic ESM return code description
Description	This function is called during the state transition from PREOP to INIT or BOOT to INIT.

Prototype:	**UINT16 APPL_StartInputHandler (UINT16 *pIntMask)**	
Parameter	pIntMask	Value for register 0x204 (AL Event Mask).
Return	See generic ESM return code description	
Description	This function is called during the state transition from PREOP to SAFEOP (even if no input process data is available).	

Prototype:	**UINT16 APPL_StopInputHandler (void)**
Parameter	Void
Return	See generic ESM return code description
Description	This function is called during the state transition from SAFEOP to PREOP(even if no input process data is available).

Prototype:	**UINT16 APPL_StartOutputHandler (void)**
Parameter	Void
Return	See generic ESM return code description
Description	This function is called during the state transition from SAFEOP to OP (even if no output process data is available).

Prototype:	**UINT16 APPL_StopOutputHandler (void)**
Parameter	Void
Return	See generic ESM return code description
Description	This function is called during the state transition from OP to SAFEOP(even if no output process data is available).

Prototype:	**UINT16 APPL_GenerateMapping (UINT16 *pInputSize, UINT16 *pOutputSize)**
Parameter	Pointer to two 16bit variables to store the process data size. pInputSize : Input process data (Slave -> Master). pOutputSize : Output process data (Master - > Slave).
Return	See generic ESM return code description
Description	This function is called when the transition from PREOP to SAFEOP is requested by the EtherCAT master. This function shall calculate the process data size in bytes The values are required to check the SyncManager settings and for the generic process data handling.

Prototype:	**void APPL_AckErrorInd(UINT16 stateTrans)**	
Parameter	stateTrans : Indicates the current state transition .	
Return	Void	
Description	This function is called when the master acknowledge and Error.	

6.2.3 Process data handling

Prototype:	**void APPL_InputMapping(UINT16 *pData)**	
Parameter	pData	Pointer to the input process data.
Return	Void	
Description	This function is called after the application call to map the input process data to the generic stack (The generic stack will copy the data to the SM buffer).	

Prototype:	**void APPL_OutputMapping(UINT16 *pData)**	
Parameter	pData	Pointer to the output process data.
Return	Void	
Description	This function is called before the application call to get the output process data.	

6.2.4 Mailbox handling

Prototype:	**void(*pAPPL_EoeReceive)(UINT16 *pData, UINT16 length)**	
Parameter	pData length	pointer to the received frame length of the received frame
Return	Void	
Description	This function is called by the SSC if a new Ethernet frame is received via EoE. The memory is freed after the function is called. The response shall be send via "EOE_SendFrameRequest()" (chapter 6.1). This function pointer will be reset in MainInit().	

Prototype:	**void(*pAPPL_EoeSettingInd)(UINT16 *pMac, UINT16 *pIp, UINT16 *pSubNet, UINT16 *pDefaultGateway, UINT16 *pDnsIp)**	
Parameter	pMac	pointer to configured MAC address
	pIp	pointer to configured IP address
	pSubNet	pointer to configured Subnet mask address
	pDefaultGateway	pointer to configured default gateway address
	pDnsIp	pointer to configured DNS server IP address
Return	Void	
Description	This function is called by the SSC if a new EoE settings are written. This function pointer will be reset in MainInit().	

Prototype:	**UINT16 (*pAPPL_FoeRead)(UINT16 MBXMEM * pName, UINT16 nameSize, UINT32 password, UINT16 maxBlockSize, UINT16 *pData)**	
Parameter	pName	Pointer to the name of the file (the pointer is null if the function is called due to a previous busy state)
	nameSize	Length of the file name (the value is 0 if the function is called due to a previous busy state)
	password	Password for the file read (the value is 0 if the function is called due to a previous busy state)
	maxBlockSize	Maximum size of a data block (copied to pData)
	pData	Destination pointer for the first FoE fragment

Return

block size:

< FOE_MAXBUSY-101	(0x7F95)

busy:

FOE_MAXBUSY-100 (0%)	(0x7FFA - 0x64)
...	
FOE_MAXBUSY (100%)	(0x7FFA)

error:

ECAT_FOE_ERRCODE_NOTDEFINED (0x8000)
ECAT_FOE_ERRCODE_NOTFOUND (0x8001)
ECAT_FOE_ERRCODE_ACCESS (0x8002)
ECAT_FOE_ERRCODE_DISKFULL (0x8003)
ECAT_FOE_ERRCODE_ILLEGAL (0x8004)
ECAT_FOE_ERRCODE_EXISTS (0x8006)
ECAT_FOE_ERRCODE_NOUSER (0x8007)

Description

The function is called when a file read request was received. The Foe fragments shall always have the length of "maxBlockSize" till the last file fragment. In case that the file size is a multiple of "maxBlockSize" 0 shall be returned after the last fragment.
This function pointer will be reset in MainInit().

Prototype:	**UINT16(*pAPPL_FoeReadData)(UINT32 offset, UINT16 maxBlockSize, UINT16 *pData)**
Parameter	offset File offset which shall be transmitted next maxBlockSize Maximum size of a data block (copied to pData) pData Destination pointer for the first FoE fragment
Return	block size: < FOE_MAXBUSY-101 (0x7F95) busy: FOE_MAXBUSY-100 (0%) (0x7FFA - 0x64) ... FOE_MAXBUSY (100%) (0x7FFA) error: ECAT_FOE_ERRCODE_NOTDEFINED (0x8000) ECAT_FOE_ERRCODE_NOTFOUND (0x8001) ECAT_FOE_ERRCODE_ACCESS (0x8002) ECAT_FOE_ERRCODE_DISKFULL (0x8003) ECAT_FOE_ERRCODE_ILLEGAL (0x8004) ECAT_FOE_ERRCODE_EXISTS (0x8006) ECAT_FOE_ERRCODE_NOUSER (0x8007)
Description	The function is called to transmit FoE read data 2 .. n (the slave received an acknowledge on a previous accepted file read request). The Foe fragments shall always have the length of "maxBlockSize" till the last file fragment. In case that the file size is a multiple of "maxBlockSize" 0 shall be returned after the last fragment. This function pointer will be reset in MainInit().

Prototype:	**void(*pAPPL_FoeError)(UINT32 errorCode)**
Parameter	errorCode Error code send by the EtherCAT master
Return	void
Description	The function is called when the master has send an FoE Abort. This function pointer will be reset in MainInit().

Prototype:	**UINT16 (*pAPPL_FoeWrite)(UINT16 MBXMEM * pName, UINT16 nameSize, UINT32 password)**
Parameter	pName Pointer to the name of the file. nameSize Length of the file name. password Password for the file read.)
Return	0 in case that the write access is valid or one of the following error codes: ECAT_FOE_ERRCODE_NOTDEFINED (0x8000) ECAT_FOE_ERRCODE_NOTFOUND (0x8001) ECAT_FOE_ERRCODE_ACCESS (0x8002) ECAT_FOE_ERRCODE_DISKFULL (0x8003) ECAT_FOE_ERRCODE_ILLEGAL (0x8004) ECAT_FOE_ERRCODE_EXISTS (0x8006) ECAT_FOE_ERRCODE_NOUSER (0x8007)
Description	This function is called on a received FoE write request. No busy response shall be returned by this function. If the slave requires some time to handle the incoming data the function pAPPL_FoeData() shall return a busy. This function pointer will be reset in MainInit().

Prototype:	**UINT16(*pAPPL_FoeWriteData)(UINT16 MBXMEM * pData, UINT16 Size, BOOL bDataFollowing)**
Parameter	pData Received file data Size Length of received file data bDataFollowing TRUE if more FoE Data requests are following
Return	0 in case that the data access is valid or one of the following values: busy: FOE_MAXBUSY-100 (0%) (0x7FFA - 100) ... FOE_MAXBUSY (100%) (0x7FFA) error: ECAT_FOE_ERRCODE_NOTDEFINED (0x8000) ECAT_FOE_ERRCODE_NOTFOUND (0x8001) ECAT_FOE_ERRCODE_ACCESS (0x8002) ECAT_FOE_ERRCODE_DISKFULL (0x8003) ECAT_FOE_ERRCODE_ILLEGAL (0x8004) ECAT_FOE_ERRCODE_EXISTS (0x8006) ECAT_FOE_ERRCODE_NOUSER (0x8007)
Description	This function is called on a received FoE data request. This function pointer will be reset in MainInit().

6.2.4.1 Backup Parameter Support

In case that the Backup Parameter handling (chapter 8.1.1) is enabled the following functions need to be implemented.

Prototype:	**void EE_ResetFlashData(void)**	
Parameter	void	
Return	void	
Description	This function shall clear the backup parameter memory. It is called from "*InitDefaultEntries()*"	

Prototype:	**UINT32 EE_GetChecksum(void)**	
Parameter	void	
Return	UINT32	Checksum over the stored backup data
Description	This function shall return a 32Bit Crc for the backup parameter memory. The return value is stored in 0x10F0.1	

Prototype:	**UINT8 EE_IsDefaultDataInitialized(void)**	
Parameter	void	
Return	UINT8	0 if the backup parameter memory was not initialized yet. <>0 if the memory was initialized
Description	The function is called on slave power up (from "*COE_ObjInit()*") and shall check if the backup parameter memory was already initialized.	

Prototype:	**void EE_StoreDefaultData(void)**
Parameter	void
Return	void
Description	The function is called after the default parameter values are written to the memory. Called from "*InitDefaultEntries()*"

Prototype:	**void EE_LoadDefaultData(void)**
Parameter	void
Return	void
Description	The function is called before the default parameter values are read from the memory. Called from "*LoadDefaultEntries()*"

Prototype:	**void EE_ReadWordsFromNonVolatileMemory(UINT16 HUGE *pDest, UINT16 srcOffset, UINT16 n)**	
Parameter	UINT16 *	pDest : destination memory to store the data
	UINT16	srcOffset : offset within the non-volatile memory
	UINT16	n : number of words to be read
Return	void	
Description	The function shall copy the stored parameter values to referenced pointer (referencing the object entry). Called from “*LoadBackupEntries ()*”	

Prototype:	**UINT32 EE_WriteWordsToNonVolatileMemory(UINT16 destOffset, UINT16 HUGE * pSrc, UINT16 n)**	
Parameter	UINT16	dstOffset : offset within the non-volatile memory
	UINT16 *	pSrc : source memory to read the data
	UINT16	n : number of words to be read
Return	UINT32	new checksum over the whole stored data
Description	The function shall copy the data to the non-volatile memory. Called from “*InitDefaultEntries()*” ,*StoreBackupEntries()*, *COE_WriteBackupEntry()*.	

6.3 Interface Variables

Name	ApplicationObjDic
Type	Array of structure TOBJECT (see 7.5 for structure definition)
Description	Only required if the slave supports CoE. The variable shall be defined in the application header file. This array contains the application specific objects. The last element of this array shall have the index 0xFFFF.

Name	pEEPROM
Type	UINT8 *
Description	Pointer to the EEPROM buffer, it is only required if EEPROM emulation is enabled (ESC_EEPROM_EMULATION = 1). It is defined in ecatappl.h and shall be set by the application during power up (before MainInit() is called). The size of the EEPROM buffer is defined by the define ESC_EEPROM_SIZE (default 2048)

6.4 Create an Application

The most comfortable way to add a new application to the SSC is by using the **SSC Tool**. Just create a new SSC project and generate an application by selecting “Tool→Application→Create new”. The syntax for the table which will automatically open is described in chapter 13. A step-by-step instruction is available in the EtherCAT Slave Quick Design Guide ([8]).

To add a new application **manually** to the slave project all default sample applications need to be disabled (see 6). Afterwards the header file including the function definitions need to be included in the files “coeappl.c”, “ecatappl.c” and “ecatslv.c” (see “APPLICATION_FILE” comment). The corresponding ESI file needs to be created from the scratch or by adapting an existing one.

When adding an application via a **patch file**, please refer to the instructions of the application vendor. The ESI file should be provided with the application source files.

How to configure…

no mailbox support:
It is recommended that each complex EtherCAT slave supports at least the CoE mailbox protocol.
To disable the mailbox handling all protocol defines shall be set to 0 (“AOE_SUPPORTED”, “COE_SUPPORTED”, “EOE_SUPPORTED”, “FOE_SUPPORTED”, “SOE_SUPPRTED” and “VOE_SUPPORTED”).

NOTE: Even if no mailbox is supported the SyncManager0 and SyncManager1 shall just be disabled and reserved for mailbox communication. If the SM are removed the SSC need to be adapted.

input/output only device:
To create a input/output only EtherCAT slave set either “MAX_PD_INPUT_SIZE” or “MAX_PD_OUTPUT_SIZE” to 0. Otherwise these defines shall be set to the maximum process data size.

NOTE: The not used process data Sync Manager shall just be disabled. If the SM is removed the SSC need to be adapted.

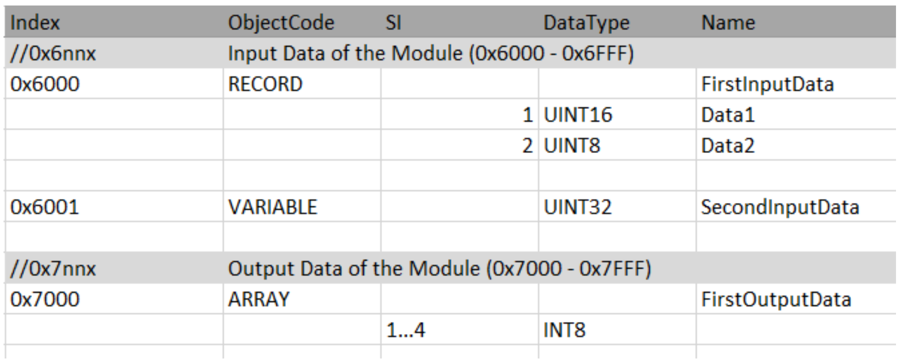
6.4.1 Examples

Examples to create application from the scratch are posted in the ETG Developers forum.

6.4.1.1 Application based on description table

The table is available via the SSC Tool (see 12.2.1.3 or [8]).

1. Describe the Input Data (Slave to Master) and Output Data (Master to Slave) required by the application (an example is shown in Figure 10). The complete Table syntax is described in the clause 13.4.



Index	ObjectCode	SI	DataType	Name
//0x6nnx	Input Data of the Module (0x6000 - 0x6FFF)			
0x6000	RECORD			FirstInputData
		1	UINT16	Data1
		2	UINT8	Data2
0x6001	VARIABLE		UINT32	SecondInputData
//0x7nnx	Output Data of the Module (0x7000 - 0x7FFF)			
0x7000	ARRAY			FirstOutputData
		1...4	INT8	

Figure 10: Application example

2. Import the table into the SSC project
   The application defined in the table is automatically imported into the SSC project either by closing the Excel file, or by selecting “Tool→Application→Import”
3. Generate the slave files.
   The source file “[TableName]Objects.h” contains the corresponding variable declarations. The variable names are created in the format: “[Name]0x[Index]”.
   In case of an array or record object a structure is created which starts with a 16bit variable “u16SubIndex0”. This variable contains the number of entries (structure variables).
   a. Object 0x6000:

```
typedef struct OBJ_STRUCT_PACKED_START {
      UINT16 u16SubIndex0;
      UINT16 Data1; /* Subindex1 - Data1 */
      UINT8 Data2; /* Subindex2 - Data2 */
} OBJ_STRUCT_PACKED_END
TOBJ6000;

PROTO TOBJ6000 FirstInputData0x6000
```

   b. Object 0x6001:

```
PROTO UINT32 SecondInputData0x600
```

   c. Object 0x7000:

```
typedef struct OBJ_STRUCT_PACKED_START {
      UINT16 u16SubIndex0;  /**< \brief Subindex 0 */
      INT8 aEntries[4];  /**< \brief Subindex 1 - 4 */
} OBJ_STRUCT_PACKED_END
TOBJ7000;

PROTO TOBJ7000 FirstOutputData0x7000
```

4. Implement the process data mapping
   The file “[TableName].c” contains the empty implementation of the Output- and Input-mapping functions for the application. These functions need to be implemented manually.
   a. Output mapping (“APPL_OutputMapping(UINT16* pData)”)

      If no specific process data mapping is defined (see 13.3) the Output Data structure is as listed:

1Byte	1Byte	1Byte	1Byte
FirstOutputData.Entry1	FirstOutputData.Entry2	FirstOutputData.Entry3	FirstOutputData.Entry4

      The mapping could be implemented via a memcpy operation:

```
memcpy(FirstOutputData0x7000.aEntries,pData,sizeof(FirstOutputData0x7000.aE
ntries);
```

   b. Input mapping (“APPL_InputMapping(UINT16* pData)”)

      If no specific process data mapping is defined (see 13.3) the Input Data structure is as listed:

2Bytes	1Byte	4Bytes
FirstInputData.Data1	FirstInputData.Data2	SecondInputData

The mapping could be implemented via the following code:

```
UINT8 *pu8Data = (UINT8 *) pData;
memcpy(&FirstInputData.Data1,pu8Data,(sizeof(FirstInputData)-2)); /* -2 is
required because the variable "SubIndex0" is not part of the process data
*/
pu8Data+=(sizeof(FirstInputData)-2);
memcpy(&SecondInputData,pu8Data,sizeof(SecondInputData));
```

5. Implement the application
   The file "[TableName].c" contains the empty implementation of the "APPL_Application()" function. In this function the logic and slave application physical signal handling shall be implemented.
6. Implement application-specific state transition handler functions
   The file "[TableName].c" contains the empty implementation of the application-specific state machine Application Interface functions (see chapter 17). In case the slave application requires to perform specific tasks during state transitions, these functions shall be implemented manually.

6.4.1.2 Sample Application process data enhancement

This example describes how to add new process data to the default sample application (SAMPLE_APPLICATION).

The default sample application provides the following process data:

- 32Bit Input Counter (0x6000)
- 32Bit Output Counter (0x7010)

If the Output Counter is 0 the Input Counter is incremented with every application cycle by 1, otherwise the Input Counter is the Output Counter +1.

Process data of the new application:

- 32Bit Input Counter (0x6000)
- 32Bit Result (0x6010)
- Output Values (0x7010)
  SI1: Value1 (32Bit)
  SI2: Value2 (32Bit)

0x6010 is the sum of 0x7010.1 and 0x7010.2. 0x6000 is incremented with every application cycle.

Initial Steps:

The initial steps describe how to create the basic sample application for the Beckhoff EL9800 EtherCAT evaluation board. Proceed with the "Adaption steps" if the basic sample application already exists (even if it was created for another platform).

1. Follow the steps 1-7 in chapter 3.1SSC Tool.
2. Select the custom configuration "EL9800 | 8Bit Digital I/O, 16Bit Analog Input"
3. Select group "Application"
   a. Set "EL9800_APPLICATION" to 0
   b. Set "SAMPLE_APPLICATION" to 1
4. Save the project and create new slave files (Project -> "Create new Slave Files")
5. Program the slave EEPROM based on the created ESI file (see "APPLICATION NOTE EL9800" for further details)
6. Create an MPLAB project with the create source files (see "APPLICATION NOTE EL9800" for further details)

Adaption steps:

1. File: sampleappl.h
   Create the entry description, the object name and the variable for the “32Bit Result” process data.

```
/***************************************************************************
*                    Object 0x6010: result object
***************************************************************************/
#ifdef _OBJD_
/* Entry description */
OBJCONST TSDOINFOENTRYDESC OBJMEM EntryDesc0x6010 = {DEFTYPE_UNSIGNED32,
0x10, ACCESS_READ | OBJACCESS_TXPDOMAPPING};
/* Object name */
OBJCONST UCHAR OBJMEM aName0x6010[] = "Result";
#endif //#ifdef _OBJD_
/* Variable to handle the object data */
PROTO UINT32 ResultObj6010;
```

2. File: sampleappl.h
   Change the existing definition of object 0x7010 (32Bit Output Counter) to a record object which handles more than one process data (the new object shall include two variables (entries)).
   The variable for the entry description is changed to an array and the description for SubIndex0 and for the second variable is added.
   The name variable is enhanced by the names for the entries (each “subname” is terminated by “\000” and the whole string is terminated by “\377”).
   For the object data itself a structure including a variable for the subindex0 and the two process data variables is defined.
   See chapter 11 for detailed information regarding the definitions.

```
/***************************************************************************
*                    Object 0x7010: output values object
***************************************************************************/
#ifdef _OBJD_
OBJCONST TSDOINFOENTRYDESC    OBJMEM asEntryDesc0x7010[] = {
/* Entry description of Subindex0 */
{DEFTYPE_UNSIGNED8, 0x08, ACCESS_READ},
/* Entry description of the first entry "Value1" */
{DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ | OBJACCESS_RXPDOMAPPING},
/* Entry description of the second entry "Value2" */
{DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ | OBJACCESS_RXPDOMAPPING}};

/* Name of the object and the entries */
OBJCONST UCHAR OBJMEM aName0x7010[] = "Output
values\000Value1\000Value2\000\377";
#endif //#ifdef _OBJD_

/* Structure to handle the object data*/
typedef struct OBJ_STRUCT_PACKED_START {
   UINT16   u16SubIndex0;
   UINT32   Value1;
   UINT32   Value2;
} OBJ_STRUCT_PACKED_END
TOBJ7010;

PROTO TOBJ7010 OutputData
#ifdef _SAMPLE_APPLICATION_
= {0x02, 0x00, 0x00}
#endif
;
```

3. File: sampleappl.h
   Add information about the new process data to the PDO mapping objects.
   The changed code is marked bold red.
   NOTE: This step is required to have consistent process data information.

Definition for RxPDO (0x1601) (handling the output process data)

```
/*************************************************************************
*                    Object 0x1601: RxPDO
*************************************************************************/
#ifdef _OBJD_
OBJCONST TSDOINFOENTRYDESC    OBJMEM asEntryDesc0x1601[] = {
   {DEFTYPE_UNSIGNED8, 0x8, ACCESS_READ },
   {DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ},
/* reference to the new process data. The information does NOT describe the
process data itself, that means if the process data is an UNSIGNED8 value
the deftype in this description is still UNSIGNED32*/
    {DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ}};

/* Only the object name is described all entries are automatically names as
"SubIndex 000" (000 is incremented for each entry) */
OBJCONST UCHAR OBJMEM aName0x1601[] = "RxPDO-Map\000\377";
#endif //#ifdef _OBJD_

typedef struct OBJ_STRUCT_PACKED_START {
   UINT16   u16SubIndex0;
/* Add one additional array element for the reference to the new process
data */
   UINT32   aEntries[2];
} OBJ_STRUCT_PACKED_END
TOBJ1601;

PROTO TOBJ1601 RxPDOMap
#ifdef _SAMPLE_APPLICATION_
 = {2/*the object has now two entries*/, {0x70100120,0x70100220/* Reference
to object 0x07010 Subindex2 and 32Bit length */}}
#endif
;
```

Definition for TxPDO (0x1A00) (handling the input process data)

```
/*************************************************************************
*                    Object 0x1A00: TxPDO
*************************************************************************/
#ifdef _OBJD_
OBJCONST TSDOINFOENTRYDESC    OBJMEM asEntryDesc0x1A00[] = {
   {DEFTYPE_UNSIGNED8, 0x8, ACCESS_READ },
   {DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ},
/* reference to the new process data. The information does NOT describe the
process data itself, that means if the process data is an UNSIGNED8 value
the deftype in this description is still UNSIGNED32*/
   {DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ}};

/* Only the object name is described all entries are automatically names as
"SubIndex 000" (000 is incremented for each entry) */
OBJCONST UCHAR OBJMEM aName0x1A00[] = "TxPDO-Map\000\377";
#endif //#ifdef _OBJD_

typedef struct OBJ_STRUCT_PACKED_START {
   UINT16   u16SubIndex0;
/* Add one additional array element for the reference to the new process
data */
   UINT32   aEntries[2];
} OBJ_STRUCT_PACKED_END
TOBJ1A00;

PROTO TOBJ1A00 TxPDOMap
#ifdef _SAMPLE_APPLICATION_
```

```
 = {2/*the object has now two entries*/, {0x60000020,0x60100020/* Reference
to object 0x06010 Subindex0 and 32Bit length */}}
#endif
;
```

4. File: sampleappl.h
   Add/Update the references in the object dictionary

```
TOBJECT    OBJMEM ApplicationObjDic[] = {
   /* Object 0x1601 */
   {NULL,NULL,  0x1601, {DEFTYPE_PDOMAPPING, 2 | (OBJCODE_REC << 8)},
asEntryDesc0x1601, aName0x1601, &RxPDOMap, NULL, NULL, 0x0000 },
   /* Object 0x1A00 */
   {NULL,NULL,   0x1A00, {DEFTYPE_PDOMAPPING, 2 | (OBJCODE_REC << 8)},
asEntryDesc0x1A00, aName0x1A00, &TxPDOMap, NULL, NULL, 0x0000 },

…

   /* Object 0x6010 */
   {NULL,NULL,   0x6010, {DEFTYPE_UNSIGNED32, 0 | (OBJCODE_VAR << 8)},
&EntryDesc0x6010, aName0x6010, &ResultObj6010, NULL, NULL, 0x0000 },
   /* Object 0x7010 */
   {NULL,NULL,   0x7010, {DEFTYPE_RECORD, 2 | (OBJCODE_REC << 8)},
asEntryDesc0x7010, aName0x7010, &OutputData, NULL, NULL, 0x0000 },
   {NULL,NULL, 0xFFFF, {0, 0}, NULL, NULL, NULL, NULL}};
```

5. File: sampleappl.c
   Update the expected process data size (which is similar to the size of the corresponding SyncManager).
   NOTE: if one of the values mismatch with the information in the ESI file the slave will abort the state transition from PreOP to SafeOP with the Error code 0x1E or 0x1D (depending on the wrong value)

```
UINT16 APPL_GenerateMapping(UINT16 *pInputSize,UINT16 *pOutputSize)
{
/* 32Bit cyclic counter (0x6000) and 32Bit Result (*0x6010)/
    *pInputSize = 8;

/*32Bit Value1 (0x7010.1) and 32Bit Value2 (0x7010.2)*/
    *pOutputSize = 8;

    return ALSTATUSCODE_NOERROR;
}
```

6. File: sampleappl.c
   Update the input process data mapping function to copy also the new process data.

```
void APPL_InputMapping(UINT16* pData)
{
    MEMCPY(pData,&InputCounter,SIZEOF(InputCounter));

/* Increment the data pointer to write the next process data (pData refers
to the buffer which is copied to the ESC memory controlled by SyncManager 3
(input process data) */
    pData +=2;

/* Copy the value the result */
    MEMCPY(pData,&ResultObj6010,SIZEOF(ResultObj6010));
}
```

7. File: sampleappl.c
   Update the output process data mapping function to update the variables handling the output process data.

```
void APPL_OutputMapping(UINT16* pData)
```

```
{
/* Update the variable "Value1" */
    MEMCPY(&OutputData.Value1,pData,SIZEOF(OutputData.Value1));

/* Increment the data pointer to write the next process data (pData refers
to the buffer which is copied to the ESC memory controlled by SyncManager 3
(input process data) */
    pData += 2;

/* Update the variable "Value2" */
    MEMCPY(&OutputData.Value2,pData,SIZEOF(OutputData.Value2));
}
```

8. File: sampleappl.c
   Update the Application.

```
void APPL_Application(void)
{
    /*Hardware independent sample application*/
      ResultObj6010 = OutputData.Value1 + OutputData.Value2;

    InputCounter++;
}
```

9. File: ESI file (in xml format)
   Update the entries of the RxPdo and TxPdo elements according to step 3.

```
<RxPdo Mandatory="true" Fixed="true" Sm="2">
      <Index>#x1601</Index>
      <Name>RxPDO</Name>
      <Entry>
            <Index>#x7010</Index>
            <SubIndex>1</SubIndex>
            <BitLen>32</BitLen>
            <Name>Value1</Name>
            <DataType>UDINT</DataType>
      </Entry>
      <Entry>
            <Index>#x7010</Index>
            <SubIndex>2</SubIndex>
            <BitLen>32</BitLen>
            <Name>Value2</Name>
            <DataType>UDINT</DataType>
      </Entry>
</RxPdo>
```

```
<TxPdo Mandatory="true" Fixed="true" Sm="3">
      <Index>#x1a00</Index>
      <Name>TXPDO</Name>
      <Entry>
            <Index>#x6000</Index>
            <SubIndex>0</SubIndex>
            <BitLen>32</BitLen>
            <Name>32Bit Input</Name>
            <DataType>UDINT</DataType>
      </Entry>
      <Entry>
            <Index>#x6010</Index>
            <SubIndex>0</SubIndex>
            <BitLen>32</BitLen>
            <Name>Result</Name>
            <DataType>UDINT</DataType>
```

```
        </Entry>
</TxPdo>
```

The information is used by the master to calculate the size of the SyncManager (it shall be equal to the size specified in step 5) and to display the process data to the user (Figure 11: RxPdo data of an EtherCAT slave).

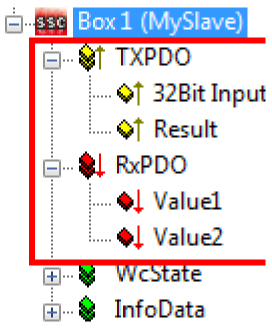


Figure 11: RxPdo data of an EtherCAT slave

10. File: ESI file
    Update the default size of SyncManager according the total bit size of the RxPdo/TxPdo entries

```
<Sm MinSize="34" MaxSize="192" DefaultSize="128" StartAddress="#x1000"
ControlByte="#x26" Enable="1">MBoxOut</Sm>

<Sm MinSize="34" MaxSize="192" DefaultSize="128" StartAddress="#x1400"
ControlByte="#x22" Enable="1">MBoxIn</Sm>

<Sm DefaultSize="8" StartAddress="#x1800" ControlByte="#x64"
Enable="1">Outputs</Sm>

<Sm DefaultSize="8" StartAddress="#x1c00" ControlByte="#x20"
Enable="1">Inputs</Sm>
```

11. File: ESI file
    Update the offline object dictionary (element: “Profile/Dictionary”).
    a. Add object 0x6010 (no structure definition is required for this object because it contains only a single base data type value).

```
<Object>
      <Index>#x6010</Index>
      <Name>Result</Name>
      <Type>UDINT</Type>
      <BitSize>32</BitSize>
      <Info>
            <DefaultData>00000000</DefaultData>
      </Info>
      <Flags>
            <Access>ro</Access>
            <Category>o</Category>
            <PdoMapping>T</PdoMapping>
      </Flags>
</Object>
```

    b. Add the new structure of object 0x7010 to the DataType definitions.

```
<DataType>
      <Name>DT7010</Name>
      <BitSize>80</BitSize>
      <SubItem>
            <SubIdx>0</SubIdx>
            <Name>SubIndex 000</Name>
            <Type>USINT</Type>
            <BitSize>8</BitSize>
            <BitOffs>0</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
      <SubItem>
            <SubIdx>1</SubIdx>
            <Name>Value1</Name>
            <Type>UDINT</Type>
            <BitSize>32</BitSize>
            <BitOffs>16</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
      <SubItem>
            <SubIdx>2</SubIdx>
            <Name>Value2</Name>
            <Type>UDINT</Type>
            <BitSize>32</BitSize>
            <BitOffs>48</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
</DataType>
```

c. Update the object 0x7010.

```
<Object>
      <Index>#x7010</Index>
      <Name>OutputCounter</Name>
      <Type>DT7010</Type>
      <BitSize>80</BitSize>
      <Info>
            <SubItem>
                  <Name>SubIndex 000</Name>
                  <Info>
                        <DefaultData>02</DefaultData>
                  </Info>
            </SubItem>
            <SubItem>
                  <Name>Value1</Name>
                  <Info>
                        <DefaultData>00000000</DefaultData>
                  </Info>
            </SubItem>
            <SubItem>
                  <Name>Value2</Name>
                  <Info>
                        <DefaultData>00000000</DefaultData>
                  </Info>
            </SubItem>
      </Info>
      <Flags>
            <Access>rw</Access>
            <Category>o</Category>
            <PdoMapping>R</PdoMapping>
      </Flags>
</Object>
```

d. Update the PDO mapping object structure.
NOTE: the definition "DT1601" can be used for object 0x1601 and object 0x1A00 because the object structures are equal.

```
<DataType>
      <Name>DT1601</Name>
      <BitSize>80</BitSize>
      <SubItem>
            <SubIdx>0</SubIdx>
            <Name>SubIndex 000</Name>
            <Type>USINT</Type>
            <BitSize>8</BitSize>
            <BitOffs>0</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
      <SubItem>
            <SubIdx>1</SubIdx>
            <Name>SubIndex 001</Name>
            <Type>UDINT</Type>
            <BitSize>32</BitSize>
            <BitOffs>16</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
      <SubItem>
            <SubIdx>2</SubIdx>
            <Name>SubIndex 002</Name>
            <Type>UDINT</Type>
            <BitSize>32</BitSize>
            <BitOffs>48</BitOffs>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
      </SubItem>
</DataType>
```

e. Update PDO mapping object.

```
<Object>
      <Index>#x1601</Index>
      <Name>RxPDO-Map</Name>
      <Type>DT1601</Type>
      <BitSize>80</BitSize>
      <Info>
            <SubItem>
                  <Name>SubIndex 000</Name>
                  <Info>
                        <DefaultData>02</DefaultData>
                  </Info>
            </SubItem>
            <SubItem>
                  <Name>SubIndex 001</Name>
                  <Info>
                        <DefaultData>20011070</DefaultData>
                  </Info>
            </SubItem>
            <SubItem>
                  <Name>SubIndex 002</Name>
```

```
                        <Info>
                              <DefaultData>20021070</DefaultData>
                        </Info>
                  </SubItem>
            </Info>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
</Object>
```

```
<Object>
            <Index>#x1a00</Index>
            <Name>TxPDO-Map</Name>
            <Type>DT1601</Type>
            <BitSize>80</BitSize>
            <Info>
                  <SubItem>
                        <Name>SubIndex 000</Name>
                        <Info>
                              <DefaultData>02</DefaultData>
                        </Info>
                  </SubItem>
                  <SubItem>
                        <Name>SubIndex 001</Name>
                        <Info>
                              <DefaultData>20000060</DefaultData>
                        </Info>
                  </SubItem>
                  <SubItem>
                        <Name>SubIndex 002</Name>
                        <Info>
                              <DefaultData>20101060</DefaultData>
                        </Info>
                  </SubItem>
            </Info>
            <Flags>
                  <Access>ro</Access>
                  <Category>o</Category>
            </Flags>
</Object>
```

7 Objects

Objects are slave application data (e.g. variables) which can be accessed by the EtherCAT master via CoE or process data communication. Furthermore the objects are used to describe the slave process data.
An object is uniquely defined by the following characteristics:

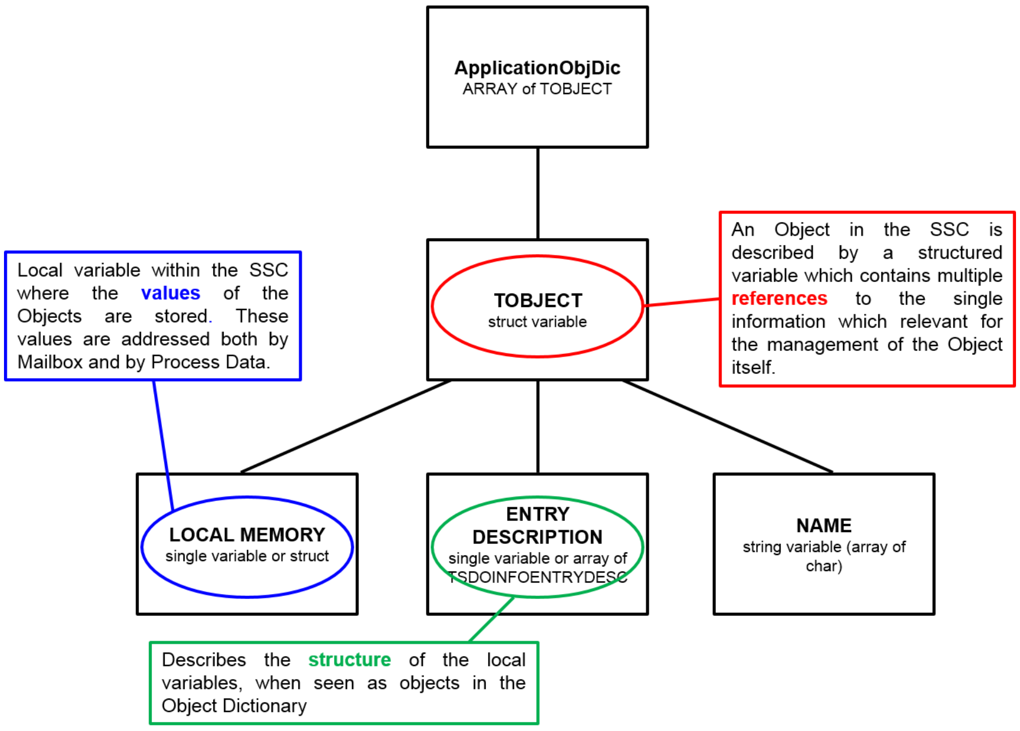

ApplicationObjDic
ARRAY of TOBJECT
TOBJECT
struct variable
An Object in the SSC is described by a structured variable which contains multiple references to the single information which relevant for the management of the Object itself.
Local variable within the SSC where the values of the Objects are stored. These values are addressed both by Mailbox and by Process Data.
LOCAL MEMORY
single variable or struct
ENTRY DESCRIPTION
single variable or array of TSDOINFOENTRYDESC
NAME
string variable (array of char)
Describes the structure of the local variables, when seen as objects in the Object Dictionary

Figure 12: Object definition schema

- Local memory (7.2 Define local memory)
- Entry Description (7.3 Entry description)
- Object Name (7.4 Object name)
- Object Description (7.5 Object description)

The characteristics for all objects are collected in one panel, the Object Dictionary. This dictionary represents the interface for the EtherCAT master access the application data via CoE. In this paragraph we classify the objects into three different Object Codes: VARIABLE, ARRAY and RECORD. The VARIABLE includes just one base data type as one object. The ARRAY is a collection of identical base data types as one object. The RECORD includes a collection of different base data types as one object.

7.1 Structure/Alignment Rules

In the implementation of the functions which provide access to the Object Dictionary, the SSC expects the following memory allocation for the CoE Objects (stack-specific, it is not derived from the ETG specification):

- All the Subindex greater 8Bit shall always start at an exact word offset from the starting address of the object itself.
- All the Subindex fields with less or equal 8-bit size shall be contained in 16-bit blocks each allocated at an exact WORD offset from the starting address of the object itself. Moreover, within each of these 16-bit blocks, the transition between the first and the second byte shall be also the transition between 2 different Subindex fields, and overall the 16-bit block shall be completely filled (it is possible of course to define padding Subindex fields (“ALIGNyy(x)” (yy : 1..15)

In case this alignment is not guaranteed, the functions in the objdef.c layer shall be adapted. Or SDO read and write callback functions shall be implemented.

7.2 Define local memory

The allocation of the local memory depends on the Object Code (VARIABLE, ARRAY or RECORD) which will be used.

In most cases for the Object Code VARIABLE it is sufficient to allocate memory by definition of a variable - if the desired object size is equal to a platform defined data type.

Example: Define local memory (Object Code VARIABLE)

```
UINT32 u32VarObject;
```

The other two Object Codes (ARRAY and RECORD) will be defined by structure. This contains an 8Bit variable as first member (Subindex0), which contains the highest subindex (last Object Entry). Note: in The Slave Stack Code the Subindex0 will always be defined as 16Bit variable due to alignment reasons!

Example: Define local memory (Object Code ARRAY)

```
typedef struct {
   UINT16   u16SubIndex0 ;
   UINT32   aEntries[4];
} _ARR_OBJ_DEF;

_ARR_OBJ_DEF ArrObj;
```

Example: Define local memory (Object Code RECORD)

```
typedef struct {
   UINT16   u16SubIndex0;
   UINT8    u8FirstEntry;
   UINT32   u32SecondEntry;
   INT16    i16ThirdEntry;
} _REC_OBJ_DEF;

_REC_OBJ_DEF RecObj;
```

7.3 Entry descriptions

A single entry description is defined in TSDOINFOENTRYDESC. All entry descriptions of an object are referenced in one array. In case on the object code ARRAY only the first entry need to be described.

Table 4: TSDOINFOENTRYDESC member variables

Member	Data type	Description
DataType	unsigned 16 bit	Index of the base data type defined in [REF2].
BitLength	unsigned 16 bit	bit length of the object (entry)

Member	Data type	Description
ObjAccess	unsigned 16 bit	Bit 0: Read Access in Pre-Op Bit 1: Read Access in Safe-Op Bit 2: Read Access in Op Bit 3: Write Access in Pre-Op Bit 4: Write Access in Safe-Op Bit 5: Write Access in Op Bit 6: map able in RxPDO Bit 7: map able in TxPDO Bit 8: entry will be included in backup Bit 9: entry will be included in settings Bit 10: safe inputs Bit11: safe outputs Bit12: safe parameter

Example: Object description (Object Code VARIABLE)

```
TSDOINFOENTRYDESC VarObjectEntryDesc =
{DEFTYPE_UNSIGNED32,0x20,(ACCESS_READ|OBJACCESS_TXPDOMAPPING)};
```

Example: Object description (Object Code ARRAY)

```
TSDOINFOENTRYDESC ArrObjEntryDesc[] = {
   {DEFTYPE_UNSIGNED8, 0x08, ACCESS_READ},
   {DEFTYPE_UNSIGNED32, 0x20, ACCESS_READ}};
```

Note: The object entry only describes the Subindex0 and one entry because all entries are equal.

Example: Object description (Object Code RECORD)

```
TSDOINFOENTRYDESC RecObjEntryDesc[] = {
   {DEFTYPE_UNSIGNED8, 0x08, ACCESS_READ},
   {DEFTYPE_UNSIGNED8, 0x08, ACCESS_WRITE_PREOP},
   {DEFTYPE_UNSIGNED32, 0x20, (ACCESS_WRITE|OBJACCESS_RXPDOMAPPING)},
   {DEFTYPE_INTEGER16, 0x10, ACCESS_WRITE}};
```

7.4 Object name

The Object Name is an ASCII coded name. The Object Codes VARIABLE and ARRAY are described only by one name including the escape sequence "\0".

If the Object Code is RECORD each Entry (except Subindex0) is described. Between two names the sequence "\000" is added. The escape sequence string "\000\377" is added.

Example: Object name (Object Code VARIABLE)

```
UCHAR VarObjName[] = "Test var obj";
```

Example: Object name (Object Code ARRAY)

```
UCHAR ArrObjName[] = "Array Obj";
```

Example: Object name (Object Code RECORD)

```
UCHAR RecObjName[] = "Record Obj\000First Entry\000Second Entry\000Third
Entry\000\377";
```

7.5 Object description

The object description connects all object characteristics in one type "TOBJECT" (structure "OBJECT"). The member variables of OBJECT are listed in
Table 5.

Table 5: "TOBJECT" member variables

Member	Data type	Description
Prev Entry	struct OBJECT	Pointer to previous dictionary entry. Only available if the object dictionary entries are dynamic linked (STATIC_OBJECT_DIC = 0).
Next Entry	struct OBJECT	Pointer to next dictionary entry. Only available if the object dictionary entries are dynamic linked (STATIC_OBJECT_DIC = 0).
Index	unsigned 16 bit	Object index of the described object. The object value depends on the type of EtherCAT slave and object usage (7.6Index Ranges)
ObjDesc	TSDOINFOOBJDESC (32 bit)	
Data Type	unsigned 16 bit	Includes the data type index of the object. (defined in [2])
ObjFlags	unsigned 16 bit	Bit 0-7: Max Subindex (value of subindex 0) Bit 8-15: Object Code (defined in [2])
pEntryDesc	TSDOINFOENTRYDESC *	Pointer to object description. Defined in "7.3Entry description"
pName	unsigned char *	Pointer to object name. Defined in "7.4Object name"
pVarPtr	void *	Pointer to local memory. Defined in "7.2Define local memory"
Read		Pointer to Read Function. The prototype is listed below. This function will be called when an SDO upload is received. If this pointer is NULL the standard SDO upload function is executed. Prototype: UINT8 ReadFunction (UINT16 Index, UINT8 Subindex, UINT32 Size, UINT16 MBXMEM * pData, UINT8 bCompleteAccess)

Member	Data type	Description
Write		Pointer to Write Function. The prototype is listed below. This function will be called when an SDO download is received. If this pointer is NULL the standard SDO download function is executed. Prototype: UINT8 WriteFunction(UINT16 index, UINT8 subindex, UINT32 dataSize, UINT16 MBXMEM * pData, UINT8 bCompleteAccess)
NonVolatileOffset	unsigned 16 bit	determine offset within nonvolatile memory. This value is evaluated if the object should be stored(load) as backup parameter.

Example: Object dictionary entry description (Object Code VARIABLE)

```
TOBJECT VarObj_ODEntryDesc = {0x6000, {DEFTYPE_UNSIGNED32, 0 | (OBJCODE_VAR
<< 8)}, &VarObjectEntryDesc, VarObjName, &u32VarObject, NULL, NULL, 0x0000
};
```

Example: Object dictionary entry description (Object Code ARRAY)

```
TOBJECT ArrObj_ODEntryDesc = {0x9000, {DEFTYPE_UNSIGNED32, 5 | (OBJCODE_ARR
<< 8)}, ArrObjEntryDesc, ArrObjName, &ArrObj, NULL, NULL, 0x0000 };
```

Example: Object dictionary entry description (Object Code RECORD)

```
TOBJECT RecObj_ODEntryDesc = {0x7000, {DEFTYPE_RECORD, 4 | (OBJCODE_REC <<
8)}, RecObjEntryDesc, RecObjName, &RecObj, NULL, NULL, 0x0000 };
```

7.6 Index Ranges

The index ranges depends on the used EtherCAT profile. See Ref.[5] for further information.
The Basic index ranges used in the SSC are listed in Table 6: Basic object index ranges.

Table 6: Basic object index ranges

Index Range	Description
0x0000 – 0x0FFF	Data Type Area
0x1000 – 0x1FFF	Communication Area
0x1600 – 0x19FF	RxPDO Mapping
0x1A00 – 0x1BFF	TxPDO Mapping
0x1C10 – 0x1C2F	Sync Manager PDO Assignment
0x1C30 – 0x1C4F	Sync Manager Parameters
0x2000 – 0x5FFF	Manufacturer specific Area
0x6000 – 0x6FFF	Input Area
0x7000 – 0x7FFF	Output Area
0x8000 – 0x8FFF	Configuration Area
0x9000 – 0x9FFF	Information Area

Index Range	Description
0xA000 – 0xAFFF	Diagnosis Area
0xB000 – 0xBFFF	Service Transfer Area
0xC000 – 0xEFFF	Reserved Area
0xF000h – 0xFFFF	Device Area

If the EtherCAT slave supports CiA402 drive profile the object range 0x6000 – 0xDFFF is subdivided according to [1] . The CiA402 objects used in the CiA402 sample listed in 10.1Objects.

The object indices used in the EL9800 Application are used according to the Modular device Profile (Figure 13: EL9800 Application object ranges).

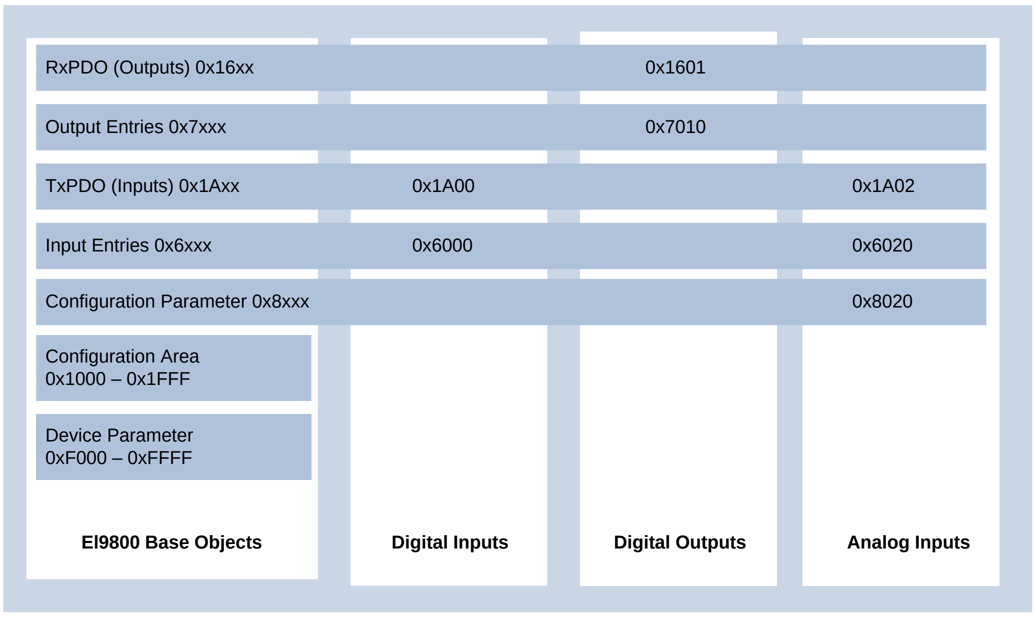


Figure 13: EL9800 Application object ranges

7.7 Implementation examples

7.7.1 Usage of Object Deftype ENUM

Each Enum Object definition shall be within the index range 0x800 – 0x0FFF. The content of an Enum definition is described in [2] .
For each enum Value a 4Byte unsigned integer Value and a Name is defined. The 4Byte unsigned integer is Byte wise Octed coded

Bsp1: "\058\000\000\000EnumValueName"
"\058" = 0*64 + 5*8 + 8*1 = 48 = 0x30
=> "EnumValueName" = 0x00000030 = 48

Bsp2: "MyValue" 0x12345678 (305419896)
0x12 to oct: 22
0x34 to oct: 64
0x56 to oct: 126
0x78 to oct: 170
=> "\017\126\064\022MyValue"

Example: Define Object Deftype ENUM

```
CHAR sEnum0801_Value00[] = "\000\000\000\000Startup"; /* Value = 0x00, Text
= Startup*/
```

```
CHAR sEnum0801_Value01[] = "\001\000\000\000Runnig"; /* Value = 0x01, Text
= Runnig*/
CHAR sEnum0801_Value02[] = "\012\000\000\000End"; /* Value = 0xA, Text =
End*/
CHAR *apEnum0801[] = { sEnum0801_Value00, sEnum0801_Value01,
sEnum0801_Value02};

OBJCONST TSDOINFOENTRYDESC    OBJMEM asEntryDesc0x0801[] =
   {{DEFTYPE_UNSIGNED8, 8, ACCESS_READ | OBJACCESS_NOPDOMAPPING},
   {DEFTYPE_OCTETSTRING, 8*SIZEOF(sEnum0801_Value00), ACCESS_READ |
OBJACCESS_NOPDOMAPPING},
   {DEFTYPE_OCTETSTRING, 8*SIZEOF(sEnum0801_Value01), ACCESS_READ |
OBJACCESS_NOPDOMAPPING},
   {DEFTYPE_OCTETSTRING, 8*SIZEOF(sEnum0801_Value02), ACCESS_READ |
OBJACCESS_NOPDOMAPPING}};
```

Example: Define Object dictionary entry: ENUM Object

```
{NULL,NULL, 0x0801, {DEFTYPE_ENUM, 0x03 | (OBJCODE_REC << 8)},
asEntryDesc0x0801, 0, apEnum0801 },
```

Example: Define New Object (using ENUM)

```
OBJCONST TSDOINFOENTRYDESC    OBJMEM sEntryDesc0x2001 = {0x801, 0x20,
ACCESS_READ };
OBJCONST UCHAR OBJMEM aName0x2001[] = "MySampleObject";
UINT32 u32MyObject = 0xA;
```

Example: Object dictionary entry description New Object (using ENUM)

```
TOBJECT MyObject_ODEntryDesc = { 0x2001, {0x801, 0 | (OBJCODE_VAR << 8)},
&sEntryDesc0x2001, aName0x2001, & u32MyObject, NULL, NULL, 0x0000 },
```

8 Mailbox

8.1 CoE (CAN application protocol over EtherCAT)

8.1.1 Backup Parameter support

The SSC supports the handling of backup parameters. Backup parameters are object entries which are can be stored in non-volatile memory.
To enable that feature set the define “BACKUP_PARAMETER_SUPPORTED” to 1.

The following entries are used to control the backup behavior.

- 0x1010.1 Store backup value (if 0x65766173 is written the backup parameters are stored, see Figure 16).
- 0x1011.1 Restore default values (if 0x64616F6C is written the default backup parameters are read, see Figure 15).
- 0x10F0.1 Checksum (readonly, contains the current checksum of the stored backup parameter data)

On power up of the slave the following functions are called (Figure 14).

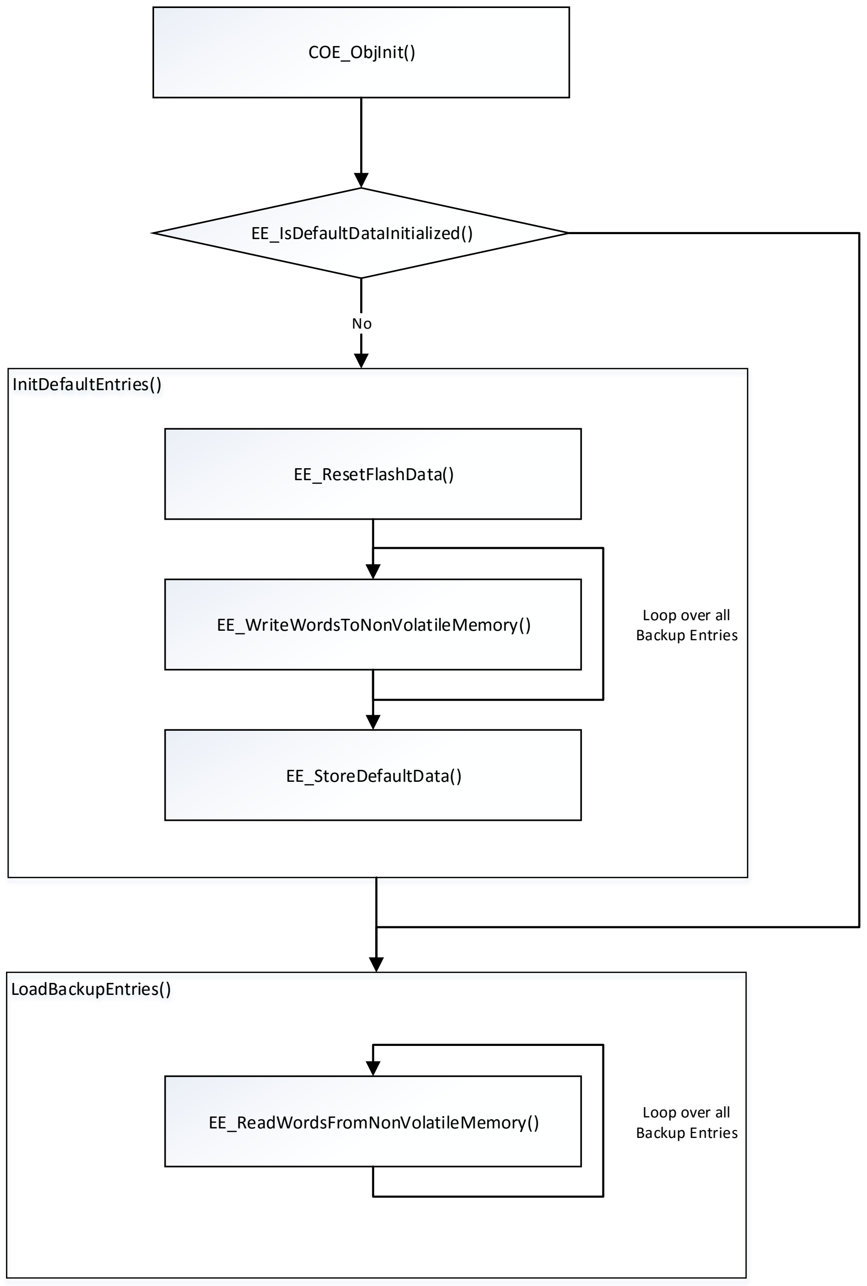

COE_ObjInit()
EE_IsDefaultDataInitialized()
No
InitDefaultEntries()
EE_ResetFlashData()
EE_WriteWordsToNonVolatileMemory()
Loop over all Backup Entries
EE_StoreDefaultData()
LoadBackupEntries()
EE_ReadWordsFromNonVolatileMemory()
Loop over all Backup Entries

Figure 14: Backup parameter Initialization

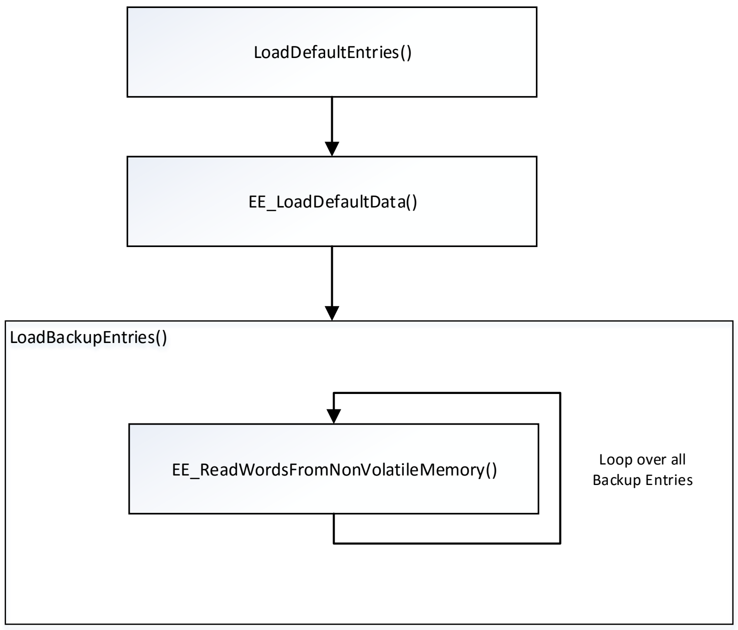

LoadDefaultEntries()
EE_LoadDefaultData()
LoadBackupEntries()
EE_ReadWordsFromNonVolatileMemory()
Loop over all Backup Entries

Figure 15: Restore the default backup parameter values

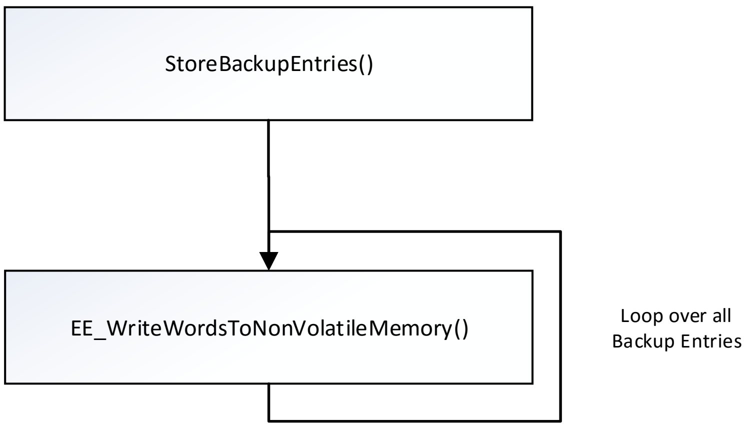

StoreBackupEntries()
EE_WriteWordsToNonVolatileMemory()
Loop over all Backup Entries

Figure 16: Store backup parameters

8.2 FoE (File Transfer over EtherCAT)

FoE can be used to download and upload a file to an EtherCAT device. The protocol is similar to TFTP service. To enable FoE set the define "*FOE_SUPPORTED*" to 1. The slave application has to implement and register the FoE callback functions (see chapter 6.2.4).

8.2.1 Testing FoE

The Slave Stack Code supports FoE not by default but it can be activated and tested:

1.) Set the define in "ecat_def.h"
    a. FOE_SUPPORTED 1
    b. SAMPLE_APPLICATION 1 (or your own application which has implemented the FOE interface, see chapter 6.2.4)
2.) Build a binary file (*.hex) (see [3])
3.) Write binary to the PIC controller of the Evaluation Kit (see Application Note EL9800 [3]).
4.) Check if FoE flag in ESI file
    a. Open ESI file (..\SlaveStackCode\VXiXX\esi\SlaveStackCode.xml)

   b. Check if the element EtherCATInfo : Descriptions : Devices : Device : Mailbox : FoE is available. It has only to be present. No content is necessary.

5.) If the ESI file was edited replace the original ESI file from TwinCAT (../Io/Ethercat/SlaveStackCode.xml) with the edited one.

6.) Rewrite SII if ESI file was edited (see[3])

7.) Restart device and restart TwinCAT

8.) Scan Network

9.) Select device (Evaluation Kit with FoE activated)

10.) Select Tab-“Online” and read or write a file to the slave device be pressing the corresponding buttons in the File Access over EtherCAT – group box.

8.3 EoE (Ethernet over EtherCAT)

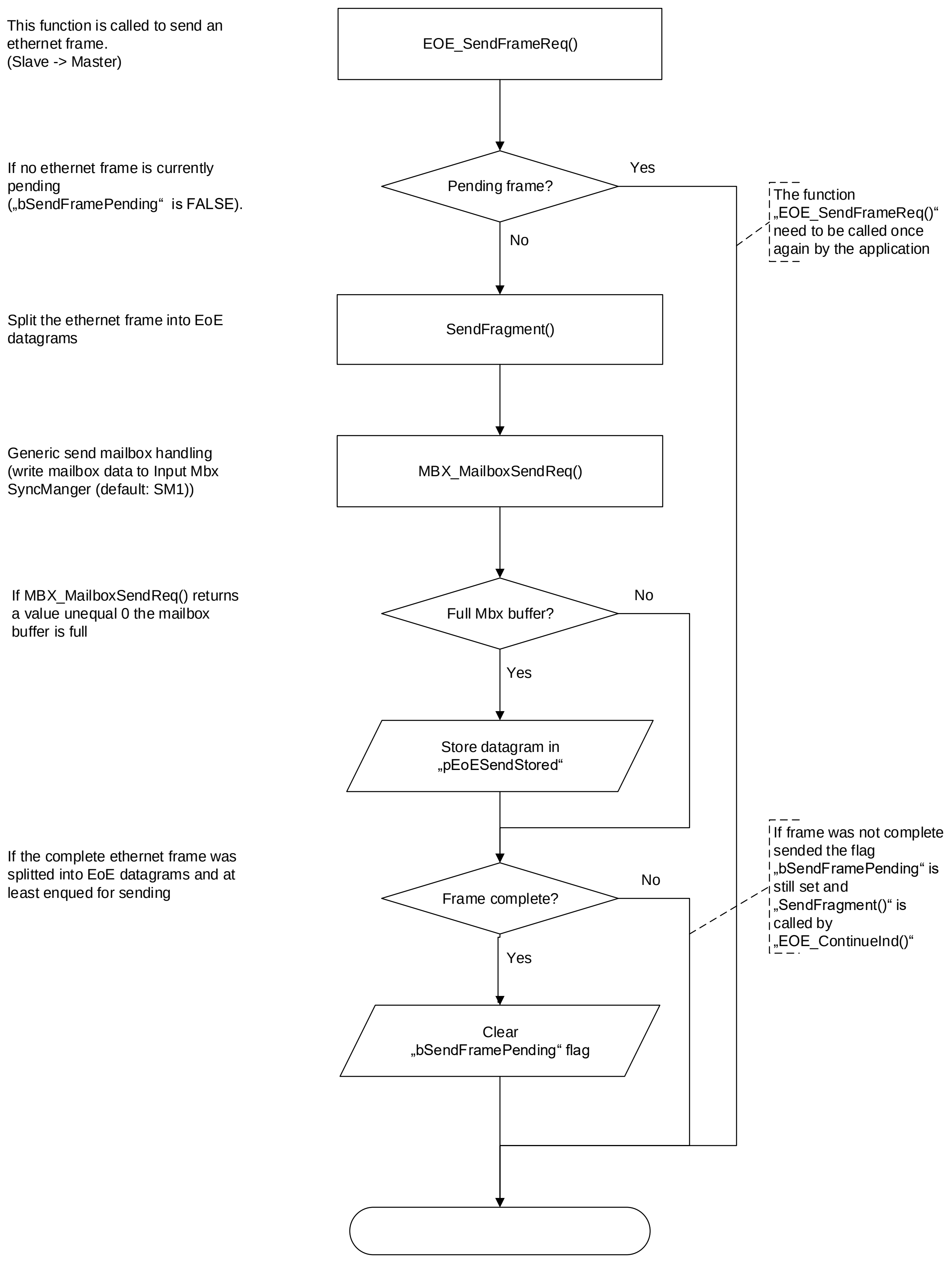
EoE is used to send Ethernet telegrams to EtherCAT devices (supporting a Ethernet stack). EoE is used for Ethernet communication i.e. a device supports a web server that can be accessed via browser.

8.3.1 Implementation

The EoE stack is Implemented in the files *ecateoe.** (basic EoE handling) and *eoeappl.** (EoE application handling).To support EoE the switch “EOE_SUPPORTED” need to be set to 1 and the EoE flag need to be set in the ESI (REF.[4]). Depending on the switch “STATIC_ETHERNET_BUFFER” dynamic memory is allocated for Ethernet frame handling or a fixed memory is used (1514 Bytes).
By default the stack only handles ICMP and ARP frames.

8.3.1.1 Sending EoE datagrams

To send EoE datagram from the EtherCAT slave to the EtherCAT master the function “EOE_SendFrameReq()” shall be called.



This function is called to send an ethernet frame. (Slave -> Master)
EOE_SendFrameReq()
If no ethernet frame is currently pending („bSendFramePending“ is FALSE).
Pending frame?
Yes
No
The function „EOE_SendFrameReq()“ need to be called once again by the application
Split the ethernet frame into EoE datagrams
SendFragment()
Generic send mailbox handling (write mailbox data to Input Mbx SyncManger (default: SM1))
MBX_MailboxSendReq()
If MBX_MailboxSendReq() returns a value unequal 0 the mailbox buffer is full
Full Mbx buffer?
No
Yes
Store datagram in „pEoESendStored“
If the complete ethernet frame was splitted into EoE datagrams and at least enqued for sending
Frame complete?
No
Yes
If frame was not complete sended the flag „bSendFramePending“ is still set and „SendFragment()“ is called by „EOE_ContinueInd()“
Clear „bSendFramePending“ flag

Figure 17: Send EoE datagram

8.3.1.2 Receiving EoE datagrams

Received EoE datagrams are handled by the function “EOE_ServiceInd()” which is called from the generic mailbox stack. The program flow is shown in Figure 18.

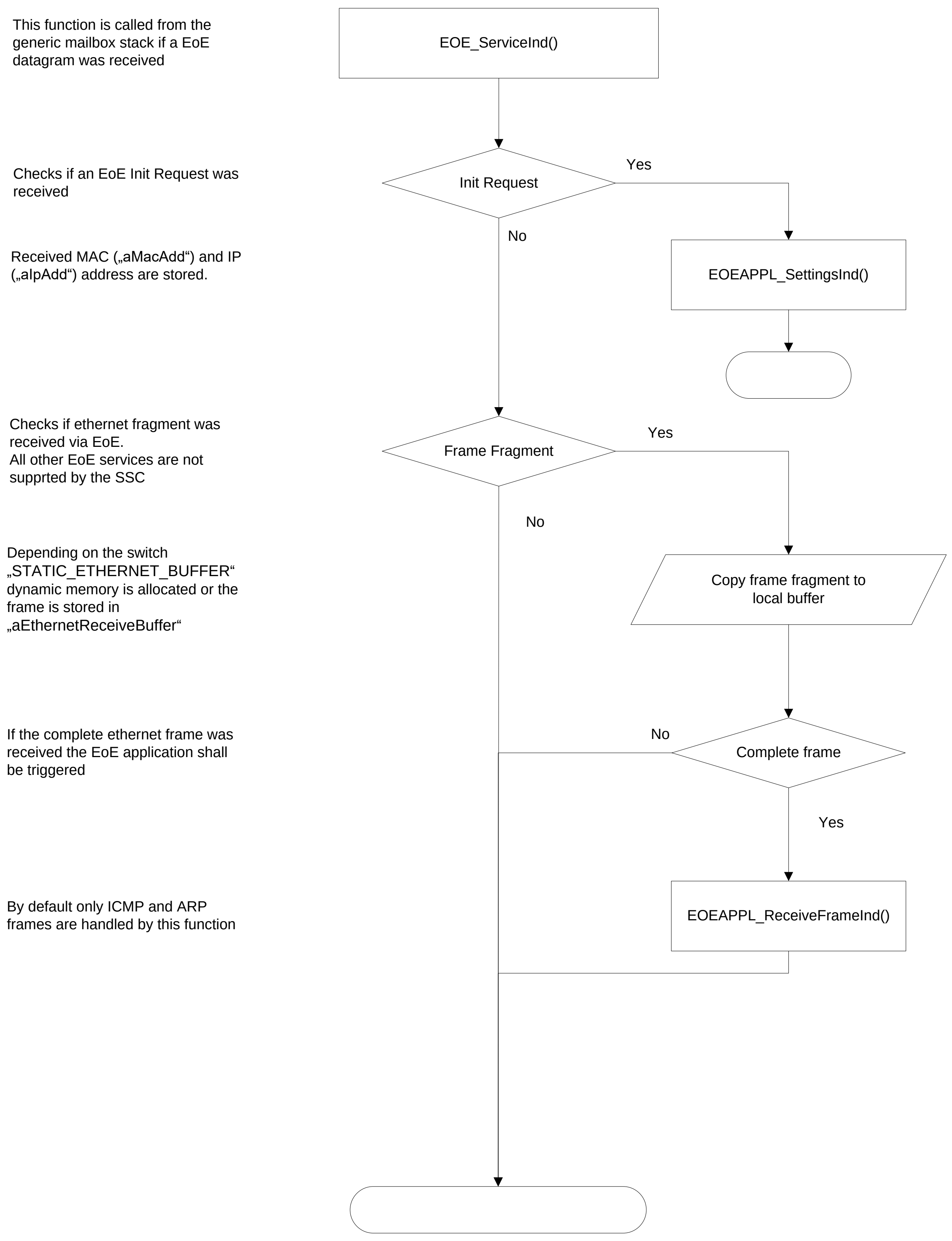

This function is called from the generic mailbox stack if a EoE datagram was received
EOE_ServiceInd()
Checks if an EoE Init Request was received
Init Request
Yes
No
Received MAC („aMacAdd“) and IP („aIpAdd“) address are stored.
EOEAPPL_SettingsInd()
Checks if ethernet fragment was received via EoE.
All other EoE services are not supprted by the SSC
Frame Fragment
Yes
No
Depending on the switch „STATIC_ETHERNET_BUFFER“ dynamic memory is allocated or the frame is stored in „aEthernetReceiveBuffer“
Copy frame fragment to local buffer
If the complete ethernet frame was received the EoE application shall be triggered
No
Complete frame
Yes
By default only ICMP and ARP frames are handled by this function
EOEAPPL_ReceiveFrameInd()

Figure 18: Receive EoE datagram

8.3.2 EoE Examples

The Sample code has a simple ping service integrated that answers to a ping request.

1.) Set the define EOE_SUPPORTED 1 (in ecat_def.h)

2.) Build a binary file (*.hex) (see [3]).

3.) Write binary to the PIC controller of the Evaluation Kit (see Application Note EL9800 [3]).

4.) Change EoE flag in ESI file

   a. Open ESI file (..\SlaveStackCode\VXiXX\esi\SlaveStackCode.xml)

   b. Open corresponding entry

      i. Board 4a (new board): EL9800-SPI-PIC24

      ii. Board 2 (former board): EL9800-SPI-PIC18

      iii. If CiA 402 example is used: EL9800-CiA402

   c. Enter the element EtherCATInfo : Descriptions : Devices : Device : Mailbox : EoE
   Only the element has to be present.

5.) Replace the original ESI file from TwinCAT (../Io/Ethercat/SlaveStackCode.xml) with the edited one.

6.) Rewrite SII (see [3]).

8.3.2.1 EoE Example 1

The prerequisite for this example are the steps described in the introduction of chapter 8.3.2 EoE Examples.
The example describes how to ping an EtherCAT slave device from a master platform (Figure 19: EoE Example 1 (Schema)).

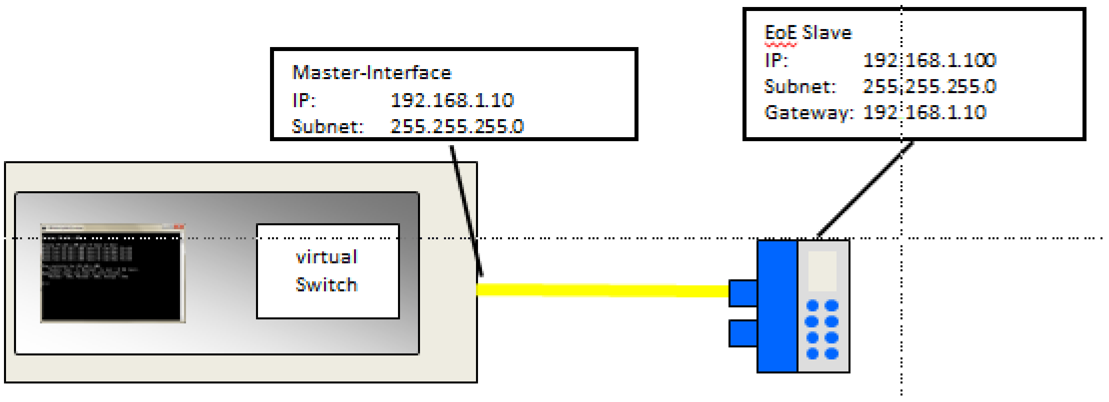


Figure 19: EoE Example 1 (Schema)

1.) Restart device and restart TwinCAT

2.) Configure Network Card NIC

   a. Open network adapter setting

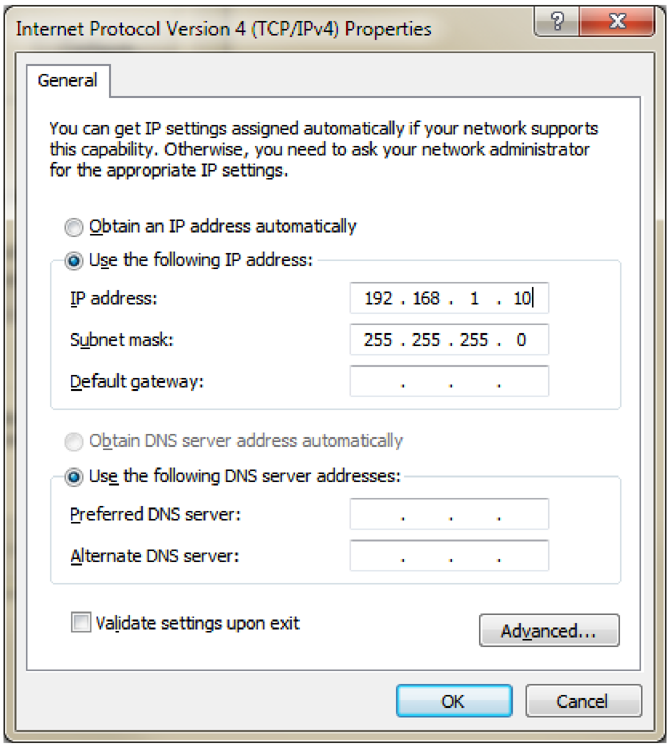
   b. Open the settings of the Network-Card that is used for EtherCAT (!)

      i. Set IP-Address of the card to the value you want to use, e.g.:

      ii. IP-Address: 192.168.1.10

      iii. Subnet Mask: 255.255.255.0

   c. Leave all other fields blank (DNS, WINS, Gateway)



Internet Protocol Version 4 (TCP/IPv4) Properties

General

You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

○ Obtain an IP address automatically
[✓ Use the following IP address:]

IP address: 192 . 168 . 1 . 10
Subnet mask: 255 . 255 . 255 . 0
Default gateway: . . .

○ Obtain DNS server address automatically
[✓ Use the following DNS server addresses:]

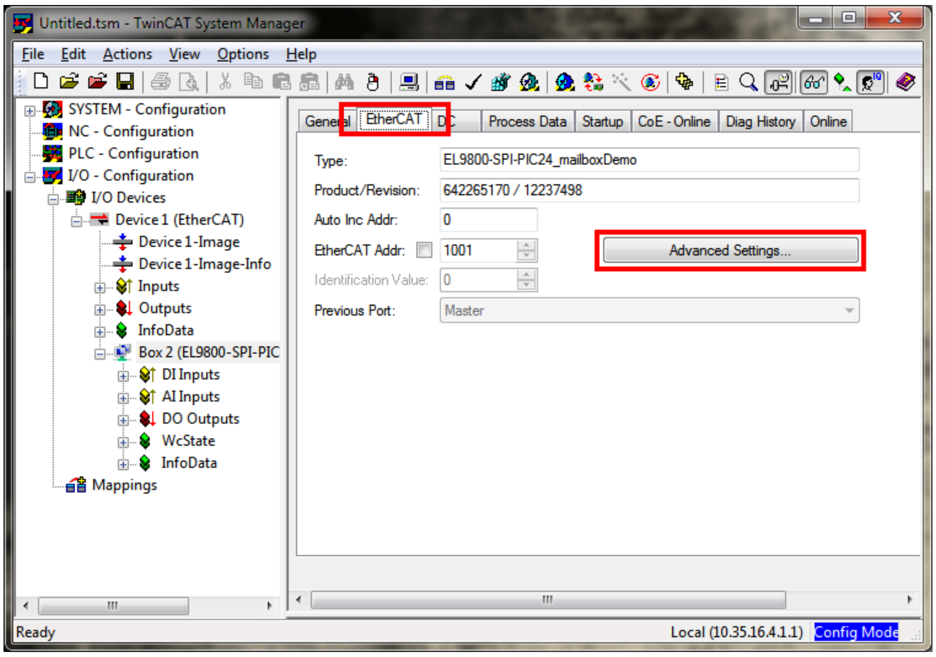
Preferred DNS server: . . .
Alternate DNS server: . . .

☐ Validate settings upon exit

Figure 20: Network card settings

3.) Save settings

a. Configure device
b. Open TwinCAT
c. Scan Network
d. Select device (Evaluation Kit with EoE activated)
e. Select EtherCAT tab and [Advanced Settings]



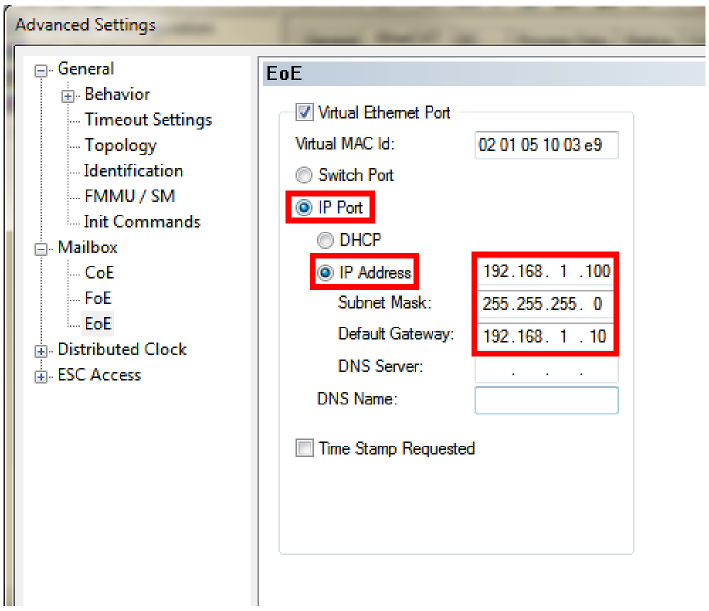
Untitled.tsm - TwinCAT System Manager

Type: EL9800-SPI-PIC24_mailboxDemo
Product/Revision: 642265170 / 12237498
Auto Inc Addr: 0
EtherCAT Addr: ☐ 1001
Identification Value: 0
Previous Port: Master

Ready Local (10.35.16.4.1.1) Config Mode

Figure 21: Access EtherCAT Slave Settings

f. Configure a IP address in the same subnet
g. Set the IP address of the NIC as gateway



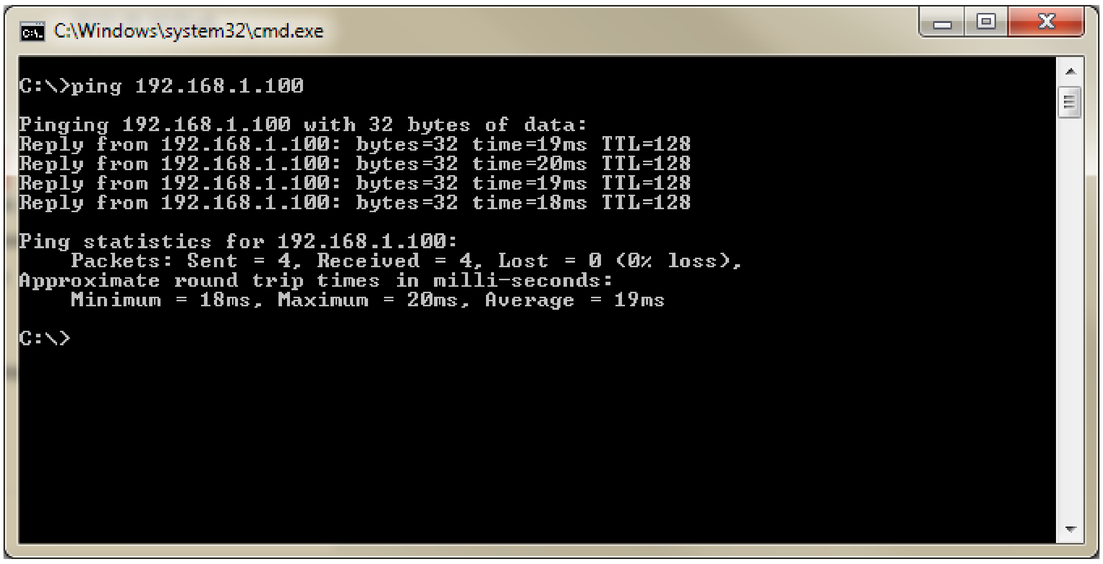
[✓] Virtual Ethernet Port
Virtual MAC Id: 02 01 05 10 03 e9
Switch Port [✓ IP Port]
DHCP [✓ IP Address]
IP Address: 192.168. 1 .100
Subnet Mask: 255.255.255. 0
Default Gateway: 192.168. 1 . 10
DNS Server: . . .
DNS Name:
[ ] Time Stamp Requested

Figure 22: EoE EtherCAT Slave Settings

4.) Set network at least to PRE-OP (mailbox communication needed)

5.) Open a program supporting PING service

6.) Ping device



```
C:\>ping 192.168.1.100

Pinging 192.168.1.100 with 32 bytes of data:
Reply from 192.168.1.100: bytes=32 time=19ms TTL=128
Reply from 192.168.1.100: bytes=32 time=20ms TTL=128
Reply from 192.168.1.100: bytes=32 time=19ms TTL=128
Reply from 192.168.1.100: bytes=32 time=18ms TTL=128

Ping statistics for 192.168.1.100:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 18ms, Maximum = 20ms, Average = 19ms

C:\>
```

Figure 23: Ping Command Window

8.3.2.2 EoE Example 2

The prerequisite for this example are the steps described in the introduction of chapter 8.3.2 EoE Examples.The example describes how to ping an EtherCAT slave device from a remote PC (Figure 24: EoE Example 2 (Schema)).

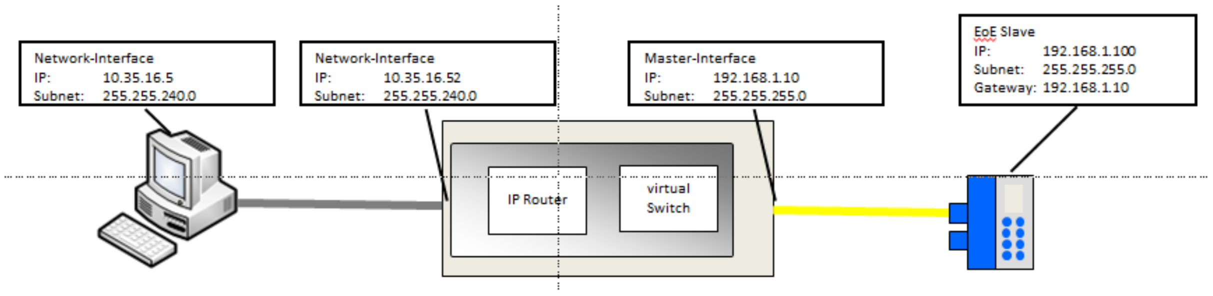


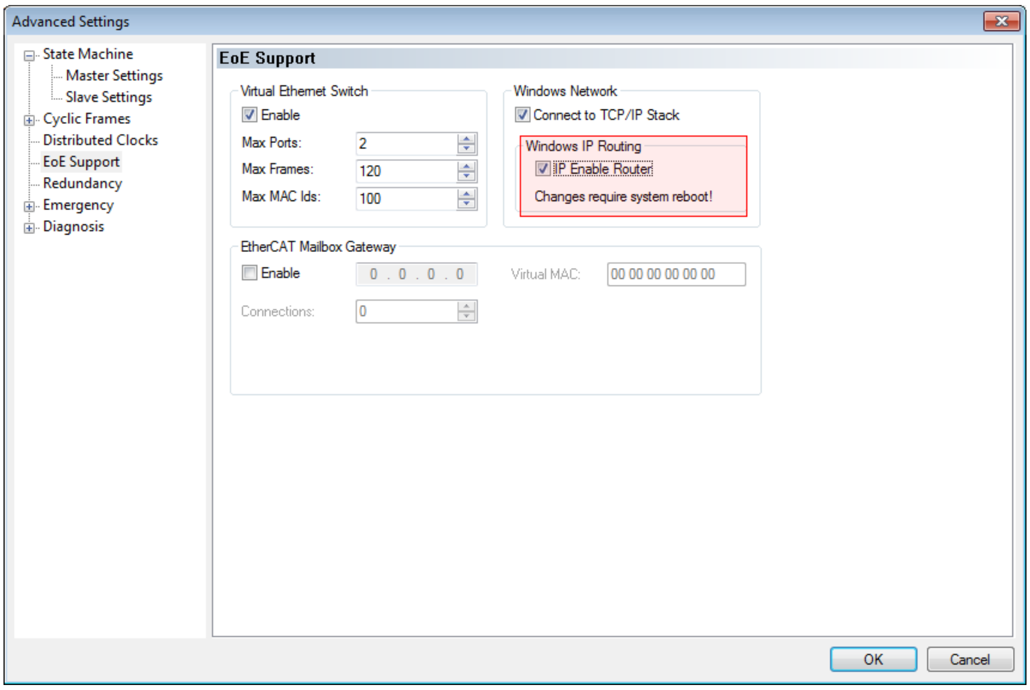
Figure 24: EoE Example 2 (Schema)

Steps 1 to 3 are equal to EoE Example 1 (chapter 8.3.2.1).

4.) Enable IP Routing on the EtherCAT Master platform. The following steps depend on the operating system.

a. Windows XP

i. Open the Advanced EtherCAT settings of the Master interface and select "IP Enable Router"().



EoE Support

Virtual Ethernet Switch
- [✓] Enable
- Max Ports: 2
- Max Frames: 120
- Max MAC Ids: 100

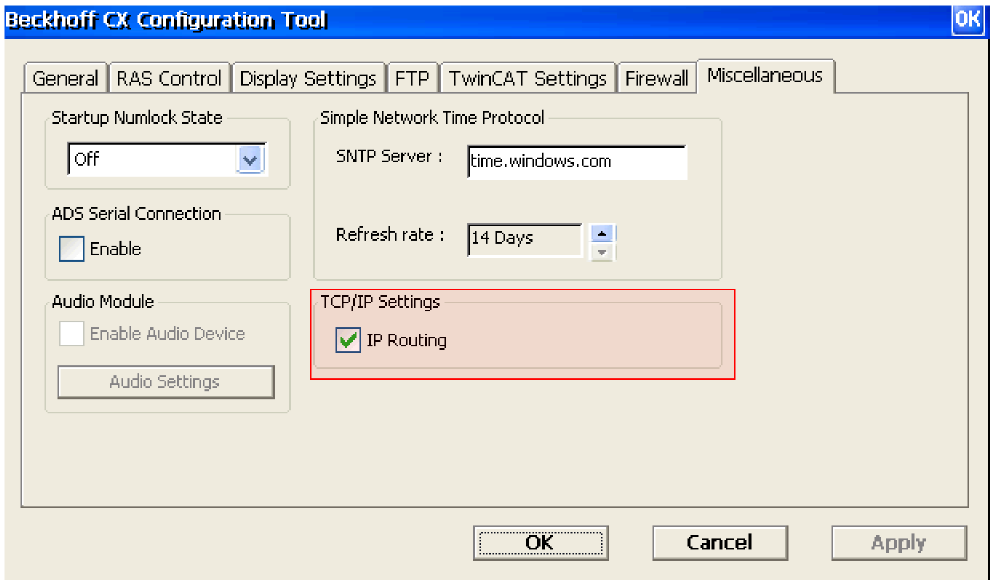
Windows Network
- [✓] Connect to TCP/IP Stack
- Windows IP Routing
  - [✓] IP Enable Router
  - Changes require system reboot!

EtherCAT Mailbox Gateway
- [ ] Enable 0 . 0 . 0 . 0
- Virtual MAC: 00 00 00 00 00 00
- Connections: 0

Figure 25: Enable IP Routing WinXP

b. Windows CE (CX platform)

i. Open CX Configuration Tool and enable "IP Routing".


Beckhoff CX Configuration Tool

Tabs: General | RAS Control | Display Settings | FTP | TwinCAT Settings | Firewall | Miscellaneous

Startup Numlock State: Off

ADS Serial Connection: ☐ Enable

Audio Module: ☐ Enable Audio Device; Audio Settings

Simple Network Time Protocol
SNTP Server : time.windows.com
Refresh rate : 14 Days

TCP/IP Settings: ☑ IP Routing

Figure 26: Enable IP Routing WinCE

5.) Restart the PC

6.) Add Route on the external PC

  a. Command: route ADD 192.168.1.0 MASK 255.255.255.0 10.35.16.52

7.) Ping slave device

9 Synchronization

The Slave Stack Code supports different modes of synchronisation which are based on three physical signals: *(PDI_)IRQ*, *Sync0* and *Sync1* (Figure 27: ESC Interrupt Signals).

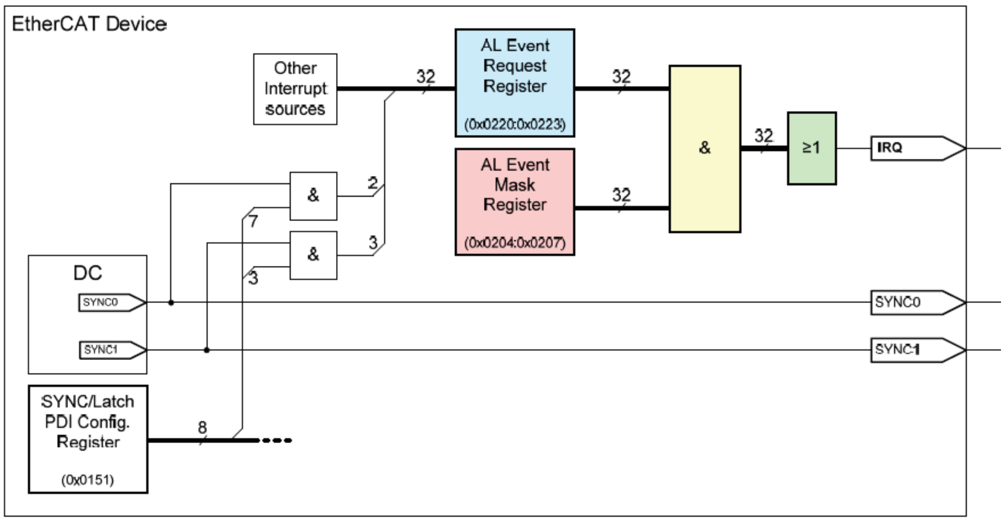

EtherCAT Device
Other Interrupt sources
32
AL Event Request Register (0x0220:0x0223)
32
AL Event Mask Register (0x0204:0x0207)
32
&
32
≥1
IRQ
&
2
7
&
3
3
DC
SYNC0
SYNC1
SYNC0
SYNC1
SYNC/Latch PDI Config. Register (0x0151)
8

Figure 27: ESC Interrupt Signals

Which of these signals are supported by the stack are based on the following defines.

AL_EVENT_ENABLED: Enable/Disable the (PDI_)IRQ support. The interrupt can be triggered by different event which are controlled by the AL event register (0x220:0x223) and the AL event mask register (0x204:0x207). For further details see the ESC datasheet. By default only the process data event (process data was written to SyncManager2 or process data was read from SyncManger3) triggers the interrupt.

DC_SUPPORTED: Enable/Disable the handling of the Sync0/Sync1 signals generated by the DC UNIT.

9.1 Supported Sync Modes

If AL_EVENT_ENABLED and DC_SUPPORTED are disabled, then the SSC is operating in Free Run (slave application is not synchronized with the EtherCAT cycle) mode.
Otherwise the synchronisation mode is configured by the SyncTypes 0x1C32.1 and 0x1C33.1 (see [7]). If no CoE is supported or no SyncType is written (during the state transition from PreOP to SafeOP), then the synchronisation mode is set based on the DC activation register (0x981, ESI element: “Dc/OpMode/AssignActivate”).
In Table 7 the supported Sync Modes are listed including the corresponding settings, if no SyncType was set before (writing 0x1C32:1 and 0x1C33:1).

Table 7: Supported Sync Modes

Sync Type	AL_EVENT_ENABLED	DC_SUPPORTED	Sync0/1 Activation (Reg. 0x981)	Sync0 Cycle time (Reg. 0x9A0:0x9A3) Sync1 Cycle time (Reg. 0x9A4:0x9A7)
Free Run*	0	--	Bit0:7: 0	--
SyncManager(SM)*	1	--	Bit0:7: 0	--
SM/Sync0*	1	1	Bit0: 1 Bit1: 1 Bit2:7: --	--
SM/Sync0/Sync1	1	1	Bit0: 1 Bit1: 1 Bit2: 1 Bit3:7: --	Sync0Cycle >= Sync1Cycle
Sync0*	0	1	Bit0: 1 Bit1: 1 Bit2:7: --	--
Sync0/Sync1	0	1	Bit0: 1 Bit1: 1 Bit2: 1 Bit3:7: --	--
Subordinated cycles	1	1	Bit0: 1 Bit1: 1 Bit2: 1 Bit3:7: --	Sync0Cycle < Sync1Cycle

*: Default sync type if no CoE is supported.

In the following chapters the supported synchronization modes are described. The terms and values in the figures are:

- PDO_OutputMapping(): Copies the output process data from the SM2 buffer to the local memory and calls APPL_OutputMapping(). See chapter 6 for further details.
- ECAT_Application(): Calls the function APPL_Application(). See chapter 6 for further details.
- PDO_InputMapping(): Calls the function APPL_InputMapping(). See chapter 6 for further details. Copy the input process data from the local memory to the SM3 buffer.
- 0x1C32.6 / 0x1C33.6 (Calc and Copy Time): Required time to copy the process data from the ESC to the local memory and calculate the output value. This can be defined by “PD_OUTPUT_CALC_AND_COPY_TIME” and “PD_INPUT_CALC_AND_COPY_TIME”. For further details see 9.2.
- 0x1C32.9 / 0x1C33.9 (Delay Time): Delay from receiving the trigger to set the output or latch the input. This can be defined by “PD_OUTPUT_DELAY_TIME” and “PD_INPUT_DELAY_TIME”.
- 0x1C32.2 / 0x1C33.2 (Cycle Time): When using DC synchronization the value is read from register 0x9A0:0x9A3. For further details see 9.2.
- 0x1C32.5 / 0x1C33.5 (Min Cycle Time): Minimum cycle time for the application. This can be specified by “MIN_PD_CYCLE_TIME”. It is the total execution time of all slave application related operations. In the SSC it is the PDO_OutputMapping(), ECAT_Application() and PDO_InputMapping(). For further details see 9.2.

9.1.1 FreeRun

In this mode there is no slave application synchronisation (see Figure 28: Free Run). The function "PDO_OutputMapping()" is called only if new output process data is available.

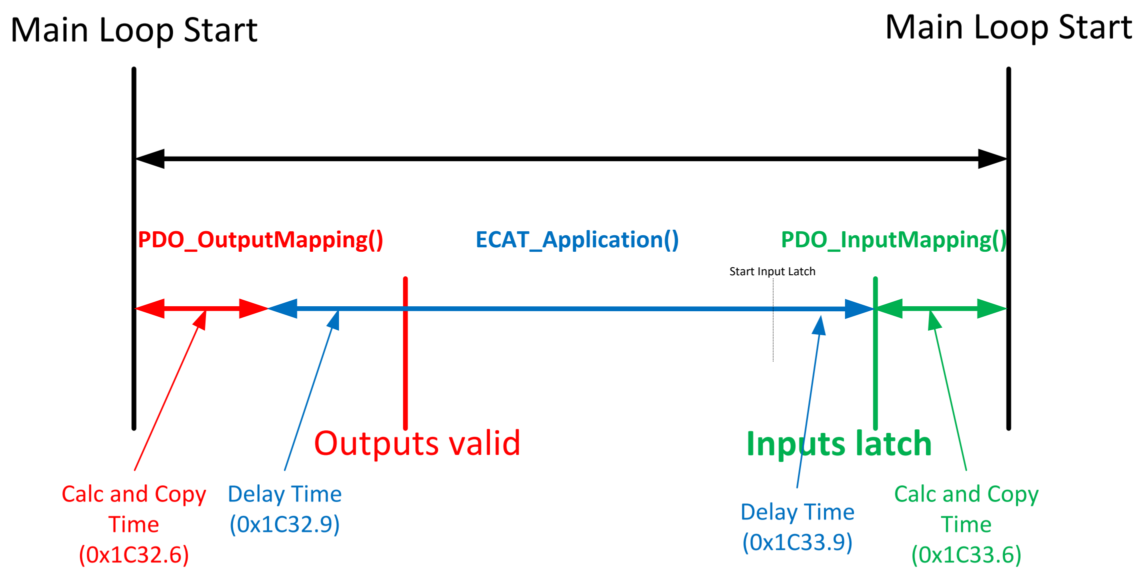


Figure 28: Free Run

<u>Free Run synchronization parameter:</u>
0x1C32.1 = 0
0x1C33.1 = 0

9.1.2 SyncManager

In this mode the slave application is executed SyncManager synchronous (Figure 29: SyncManager Synchronization). On every write event to the output process data SyncManager (SM2) the slave application is started. If the device supports only inputs, then the application is started on reading the input process data (SM3).

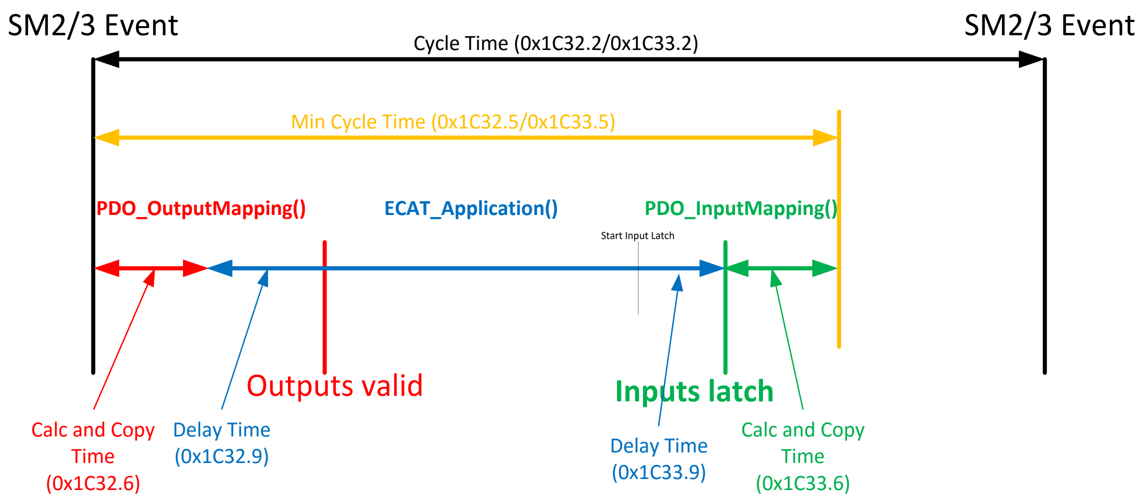


Figure 29: SyncManager Synchronization

<u>SyncManager synchronization parameter:</u>
0x1C32.1 = 0x1
0x1C33.1 = 0x22

9.1.3 SyncManager/Sync0

This mode is recommended for most applications when the Sync0-event is used for synchronization. The output process data mapping is triggered by the SM2 event and the ECAT_Application to set the output values and start the input latch is started on Sync0 (see Figure 30: SM/Sync0 Synchronization). With monitoring the SM2-event (before the Sync0-event occurs), the application ensures that there are new target values available for each local cycle. If the SM2-event is too late to complete the CalcAndCopy before the Sync0-Event occurs, the “SmEventMissed-Counter” is incremented and if the SmEventMissedLimit is exceeded the slave goes to SafeOpErr.

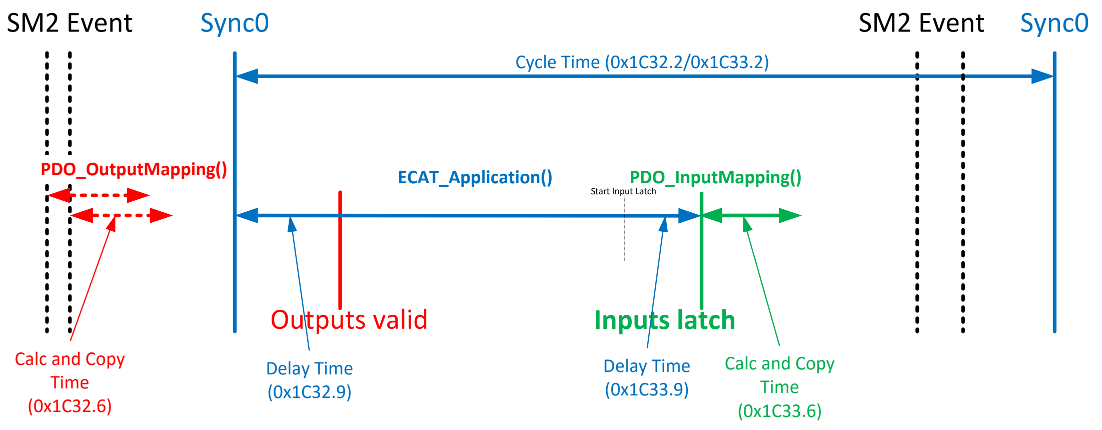


Figure 30: SM/Sync0 Synchronization

<u>SyncManager/Sync0 synchronization parameter:</u>
Sync Activation Register (0x981): Bit0, Bit1 = 1
0x1C32.1 = 2
0x1C33.1 = 2
AL_EVENT_ENABLED = 1 (if 0 see 9.1.5)

9.1.4 SyncManager/Sync0/Sync1

In this mode the output process data mapping is triggered by the SM2 event, the ECAT_Application is started on Sync0 and the input latch is started with Sync1 (see Figure 31: SM/Sync0/Sync1 Synchronization).
NOTE: The input latch shall be added to APPL_InputMapping(); by default it is done in APPL_Application()

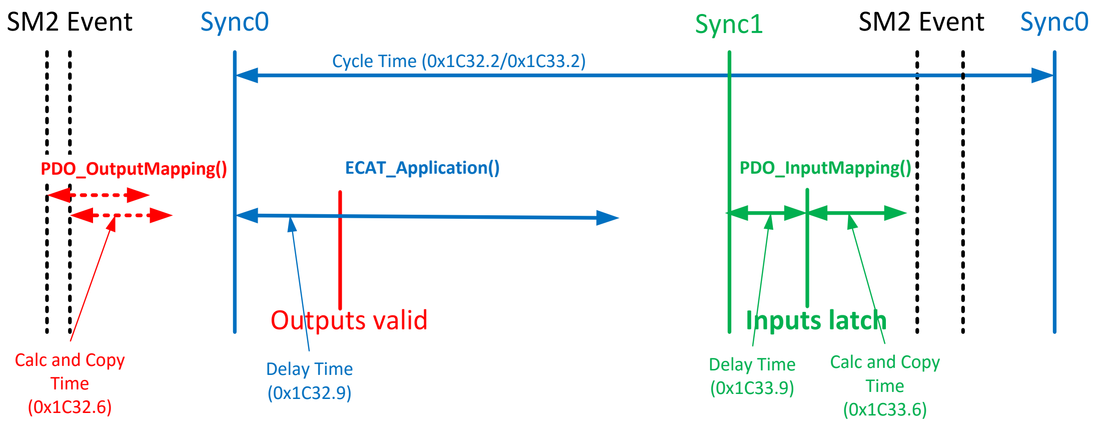


Figure 31: SM/Sync0/Sync1 Synchronization

<u>SyncManager/Sync0/Sync1 synchronization parameter:</u>
Sync Activation Register (0x981): Bit0, Bit1, Bit2 = 1
0x1C32.1 = 2
0x1C33.1 = 3
AL_EVENT_ENABLED = 1 (if 0 see 9.1.6)

9.1.5 Sync0

In this mode the slave application is started on Sync0 (see Figure 32: Sync0 Synchronization). To reduce the jitter delay between Sync0 and Outputs valid, the preferred synchronization is SyncManager/Sync0 (see chapter 9.1.3).

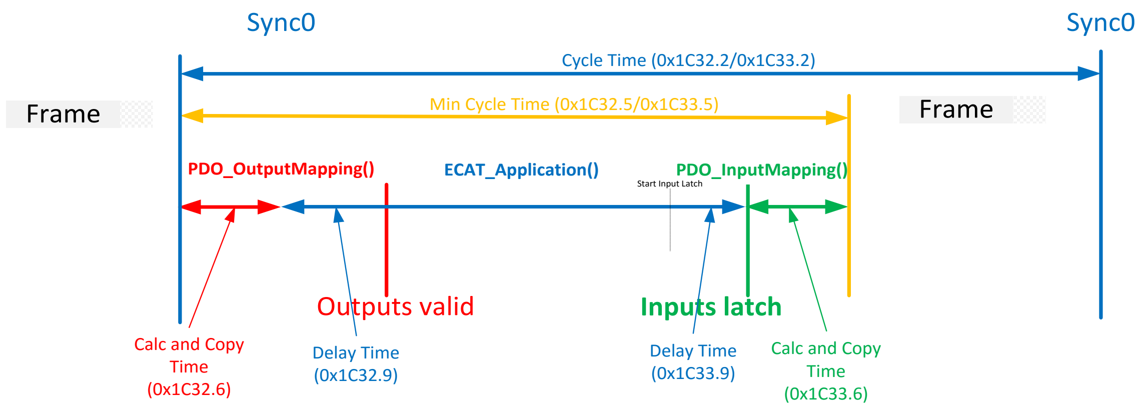


Figure 32: Sync0 Synchronization

<u>Sync0 synchronization parameter:</u>
Sync Activation Register (0x981): Bit0, Bit1 = 1
0x1C32.1 = 2
0x1C33.1 = 2
AL_EVENT_ENABLED = 0 (if 1 see 9.1.3)

9.1.6 Sync0/Sync1

The output process data mapping and the ECAT_Application is started on Sync0 and the input latch is started with Sync1 (Figure 33: Sync0/Sync1 Synchronization).
NOTE: The input latch shall be added to APPL_InputMapping(); by default it is done in APPL_Application().

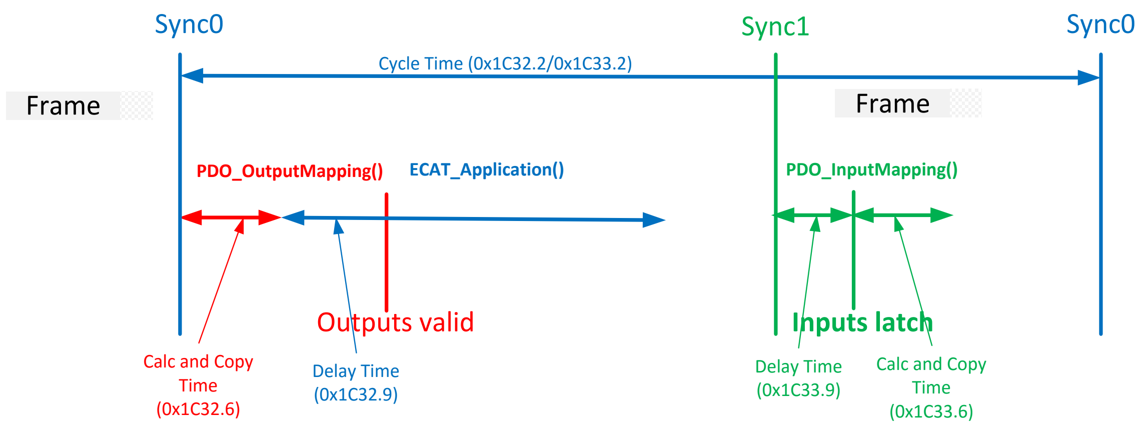


Figure 33: Sync0/Sync1 Synchronization

<u>Sync0/Sync1 synchronization parameter:</u>
Sync Activation Register (0x981): Bit0, Bit1, Bit2 = 1
0x1C32.1 = 2
0x1C33.1 = 3
AL_EVENT_ENABLED = 0 (if 1 see 9.1.4)

9.1.7 Subordinated Cycles

In this mode the output process data mapping is triggered on the SM 2 event, the ECAT_Application is started on Sync1 and each subordinated cycle is triggered with Sync0 (Figure 34: Subordinated

Cycles). The relation between Sync0 and the bus cycle is configured by the ESI element:CycleTimeSync0@Factor.

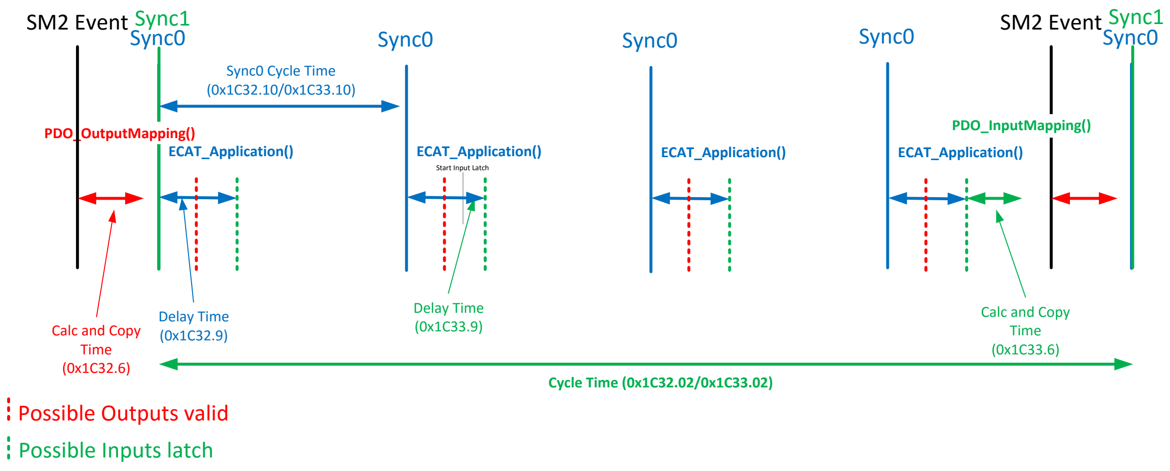


Figure 34: Subordinated Cycles

<u>Subordinated Cycles synchronization parameter:</u>
Sync Activation Register (0x981): Bit0, Bit1, Bit2 = 1
Sync0Cycle Time (0x9A0:0x9A3) < Sync1Cycle Time (0x9A4:0x9A7)
0x1C32.1 = 3
0x1C33.1 = 3
AL_EVENT_ENABLED = 1

9.2 Synchronization Timings

The configure the synchronization an EtherCAT slave may provide timing and delay information in the Sync Manager Parameter objects (0x1C3x). The Slave Stack Code provides two process data Sync Manager (SM2 handling the outputs and SM3 handling the inputs). Therefore the object 0x1C32 (related to SM2) and 0x1C33 (related to SM3) are defined.

The timings and delays in an SSC based slave application may either be fixed defined or calculated during runtime. The following values are provided:

Calc and Copy Time:

0x1C32.6:	Runtime of the function "PDO_OutputMapping()"
	Specified by: "PD_OUTPUT_CALC_AND_COPY_TIME"
0x1C33.6:	Runtime of the function "PDO_InputMapping()"
	Specified by: "PD_INPUT_CALC_AND_COPY_TIME"

Delay Time:

0x1C32.9:	(Hardware) Delay to set the physical outputs
	Specified by "PD_OUTPUT_DELAY_TIME"
0x1C33.9:	(Hardware) Delay to latch the physical inputs
	Specified by "PD_INPUT_DELAY_TIME"

Cycle Time:

0x1C32.2/0x1C33.2: In case of SM sync mode the minimum SM cycle is stored. In case of DC sync mode the Sync0 cycle time is stored

Min Cycle Time:

0x1C32.5/0x1C33.5: Minimum application cycle time (PDO_OutputMapping() + ECAT_Application() + PDO_InputMapping())

Specified by "MIN_PD_CYCLE_TIME"

Except of the delay time (0x1C3x.9) all values can be measured. To enable the measurement the corresponding defines shall be set to 0 and the entry “Get Cycle Time” (0x1C3x.9) shall be set to 1. The measurement should only be enabled once in Operational to get the timings for the current configuration.

NOTE: The timing values are based on the System time register (0x910) therefore the DC Unit has to enabled.

10 CiA402 drive profile

Since version 4.30 the Slave Stack Code contains a sample implementation of the CiA402 drive profile as described in [1] . This implementation provides the interface between the motion controller application and communication layer.

Following features are supported:

- CiA402 objects (see chapter 10.1 Objects)
- CiA402 state machine (see chapter 10.2 State machine)
- This implementation supports cyclic synchronous position (csp) and cyclic synchronous velocity (csv) operation modes.

CiA402 specific files:

`cia402appl.c` : CiA402 drive profile implementation

`cia402appl.h` : Drive profile specific objects, definitions and axes structures

All motion controller related values are encapsulated in structure `TCiA402Axis` (file: `cia402appl.h`). The configuration parameters and error codes are directly mapped to the corresponding objects. The process data objects are updated in the input/output mapping functions (file: `ecatappl.c`). Currently the sample supports maximum of two axes. The axes are initialized in the EtherCAT state change from PREOP to SAFEOP.

The motion controller is a simple integration, which just copies the target values to the actual values (see chapter 10.3 Operation modes).

10.1 Objects

All CiA402 specific objects are defined in file `cia402appl.h`.

All mandatory and some optional object are defined in this sample implementation. Table 8 contains a list of all defined objects. The object variables are located in the structure `CiA402Objects`.

Table 8: Object definitions in file `cia402appl.h`

Index	Object name	Variable in source code	Comment/Description
0x1600	Rx PDOs	`sRxPDOMap0`	includes all objects required for dynamic change between csv/csp
0x1601	Rx PDOs	`sRxPDOMap1`	includes objects required for csp mode of operation
0x1602	Rx PDOs	`sRxPDOMap2`	includes objects required for csv mode of operation
0x1A00	Tx PDOs	`sTxPDOMap0`	includes all objects required for dynamic change between csv/csp
0x1A01	Tx PDOs	`sTxPDOMap1`	includes objects required for csp mode of operation
0x1A02	Tx PDOs	`sTxPDOMap2`	includes objects required for csv mode of operation
0x1C12	SyncManger 2 PDO assign (Rx PDOs)	`sRxPDOassign`	this object is written in change state from PREOP to SAFEOP; the configuration depends on the number of axes (not include in `CiA402Objects`)
0x1C13	SyncManger 3 PDO assign (Tx PDOs)	`sTxPDOassign`	equal to 0x1C12 (not include in `CiA402Objects`)
0x603F	Error Code	`objErrorCode`	this value shall be set if an error in the PDS occurs

Index	Object name	Variable in source code	Comment/Description
0x6040	Controlword	`objControlWord`	object for the output commands from the master
0x6041	Status word	`objStatusWord`	current axis status
0x605A	Quick stop option code	`objQuickStopOptionCode`	predefined ramp if an quick stop shall be performed
0x605B	Shutdown option code	`objShutdownOptionCode`	predefined action in state transition 8
0x605C	Disable operation option code	`objDisableOperationOptionCode`	predefined action in state transition 5
0x605E	Fault reaction option code	`objFaultReactionCode`	predefined action in state “Fault reaction active”
0x6060	Modes of operation	`objModesOfOperation`	requested operation mode
0x6061	Modes of operation display	`objModesOfOperationDisplay`	current operation mode
0x6064	Position actual value	`objPositionActualValue`	current position value (delivered by encoder)
0x606C	Velocity actual value	`objVelocityActualValue`	velocity feedback
0x6077	Torque actual value	`objTorqueActualValue`	currently not used (only for completion)
0x607A	Target position	`objTargetPosition`	requested Postion value (set in csp mode)
0x607D	Software position limit	`objSoftwarePositionLimit`	includes the minimum and maximum actual position limit
0x6085	Quick stop declaration	`objQuickStopDeclaration`	predefined action in state “Quick stop active”
0x60C2	Interpolation time period	`objInterpolationTimePeriod`	
0x60FF	Target velocity	`objTargetVelocity`	target velocity requested by the master
0x6502	Supported drive modes	`objSupportedDriveModes`	list of all supported operation modes

The objects from 0x6000 to 0x67FF are incremented with 0x800 for each axis (Index + `#Axis`*0x800).

10.2 State machine

Figure 35 shows the state machine described in [1] . State changes are requested by setting 0x6040 (Controlword) or by a local event (if an error occurs). If the device is in state OP the transitions 0, 1 and 2 are skipped. The option codes next to the transition lines indicate that a specific action which shall be performed in of one of these state changes.
All handled state transitions including the required Controlword, resulting state and corresponding functions are listed in Table 9: State machine. The bits 0,1,2,3 and 7 of the control word are taken into consideration in this sample implementation. Drive functions e.g.”Break applied” or “Axis function enabled” need to be activated or deactivated corresponding to the current state. In this sample these functions are handled by Boolean variables.

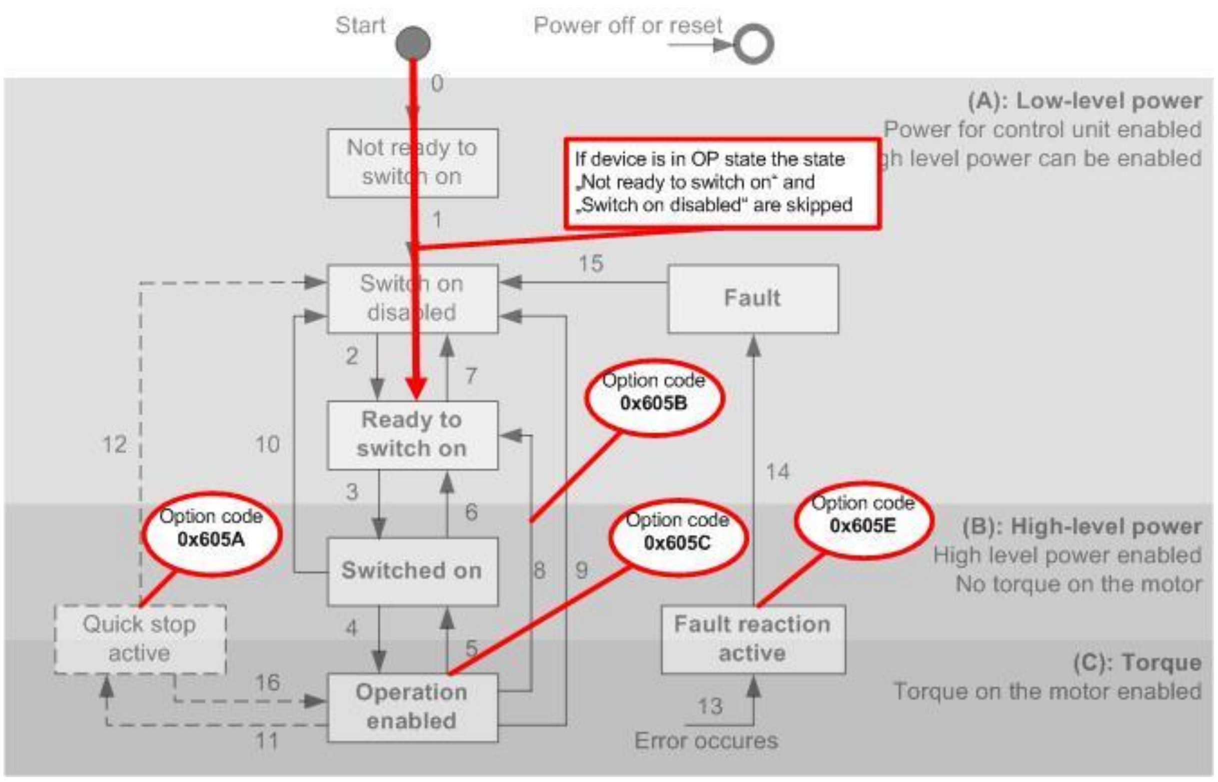


Figure 35: CiA402 state transitions and option codes

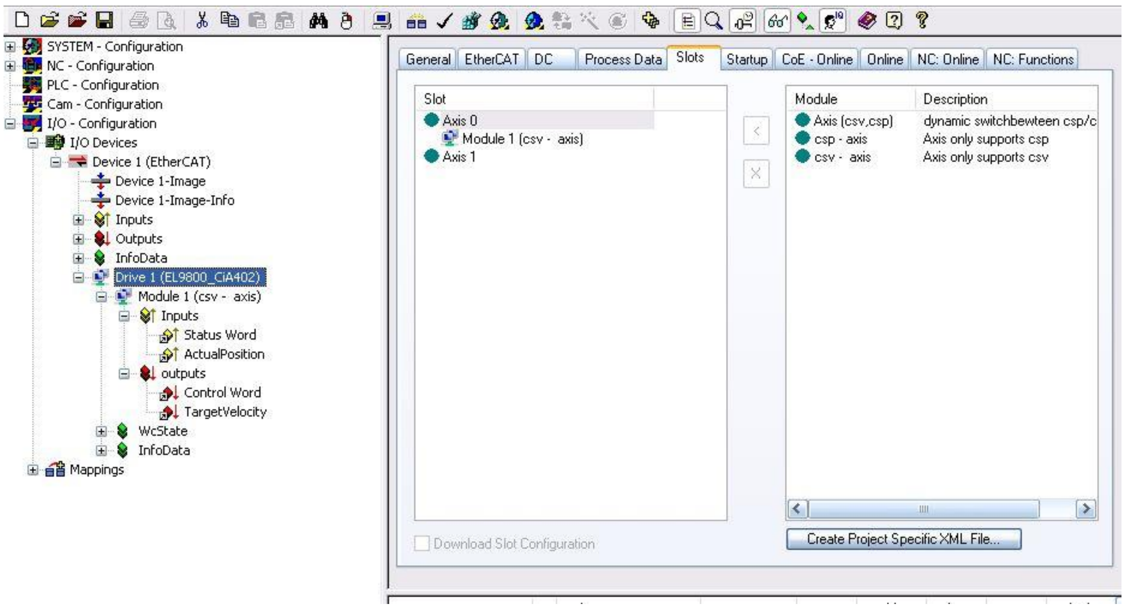
Table 9: State machine

Transition	Control word bits					Resulting state	Variable (Function)				
	Bit 7 (fault reset)	Bit 3 (enable operation)	Bit 2 (quick stop)	Bit 1 (enable voltage)	Bit 0 (switch on)		bBrakeApplied	bLowLevelPower Applied	bHighLevelPower Applied	bAxisFunction Enabled	bConfiguration Allowed
3	0	x	1	1	1	Switched on	true	true	true	false	true
4	0	1	1	1	1	Operation enabled	false	true	true	true	false
5	0	0	1	1	1	Switch on	true	true	true	false	true
6	0	x	1	1	0	Ready to switch on	true	true	false	false	true
7	0	x	x	0	x	Switch on disabled	true	true	false	false	true
	0	x	0	1	x						
8	0	x	1	1	0	Ready to switch on	true	true	false	false	true
9	0	x	x	0	x	Switch on disabled	true	true	false	false	true
10	0	x	x	0	x	Switch on disabled	true	true	false	false	true
	0	x	0	1	x						
11	0	x	0	1	x	Quick stop active	false	true	true	true	false
12	0	x	x	0	x	Switch on disbaled	true	true	false	false	true
13	Triggered by application					Fault reaction active	false	true	true	true	false
14	Transition if option code 0x605E is finished					Fault	true	true	false	false	true
15	1	x	x	x	x	Switch on disabled	true	true	false	false	true
16	After quick stop always goto “Switch on disabled”					(Operation enabled)	false	true	true	true	false

The transition number in Table 8 referring to the transition number in Figure 35.[1]

10.3 Operation modes

In general this sample supports the csv and csp mode of operation. Each axis can be configured as csv, csp or combined controller via modules (Figure 36). In last case the mode of operation can be switch dynamically. For this reason all objects required for motion control are mapped to PDOs. In the current TwinCAT Version (2.11 build 1539) the NC task doesn’t provide a variable for the objects 0x6060 (Mode of operation) and 0x6061 (Mode of operation display), so these objects values need to be directly provided by the PLC.
The motion controller function (`CiA402_DummyMotionControl()`) just copies the target velocity values to the actual velocity. The actual position is calculated by the actual velocity and the motion controller cycle time. If the device is in SM Sync mode the cycle time is calculated by an internal timer within the first application cycle. In DC Sync mode the cycle time is set to Sync0 cycle value.



SYSTEM - Configuration
NC - Configuration
PLC - Configuration
Cam - Configuration
I/O - Configuration
I/O Devices
Device 1 (EtherCAT)
Device 1-Image
Device 1-Image-Info
Inputs
Outputs
InfoData
Drive 1 (EL9800_CiA402)
Module 1 (csv - axis)
Inputs
Status Word
ActualPosition
outputs
Control Word
TargetVelocity
WcState
InfoData
Mappings

Slot
Axis 0
Module 1 (csv - axis)
Axis 1

Module	Description
Axis (csv,csp)	dynamic switchbewteen csp/c
csp - axis	Axis only supports csp
csv - axis	Axis only supports csv

Download Slot Configuration
Create Project Specific XML File...

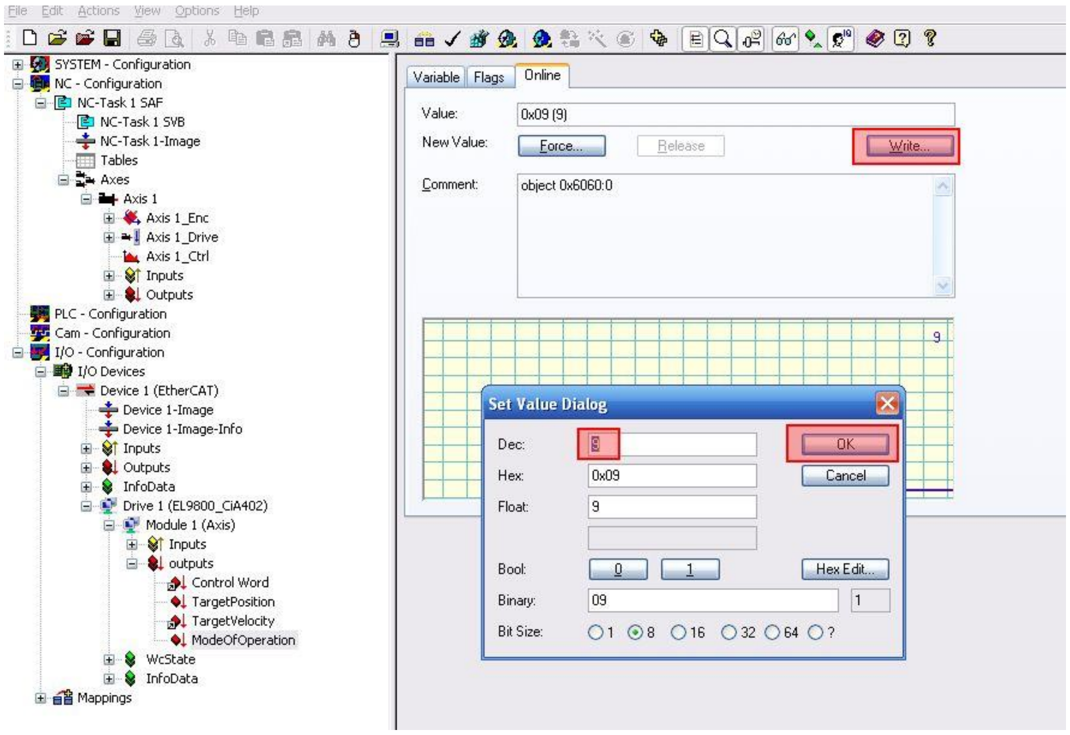
Figure 36: Axis configuration

NOTE: This sample doesn't provide a target value overflow control!

10.4 TwinCAT setup

This chapter describes the setup of motion control loop over EtherCAT. It is based on TwinCAT Version V2.11 build 1539 (major differences to TwinCAT 3 are marked in the description). At least the TwinCAT level NC is required. The position control is located on the EtherCAT master so in this case only the "target velocity" and "actual position" need to be linked to the NC task.
The mode of operation shall be set to cyclic synchronous velocity mode (csv). For the corresponding objects 0x6061 (Mode of operation display) and 0x6060 (Mode of operation) is no NC axis variable reserved. So these drive variables should be mapped direct to the PLC application.
The ModeOfOperation process data is only available if an axis module with dynamic mode switching is configured (as shown in Figure 36: Axis configuration). Otherwise it has to accessed via CoE.

For testing purposes 0x6060 (Mode of operation) could be set manually at each EtherCAT master restart.



Value: 0x09 (9)

Comment: object 0x6060:0

Dec: 9

Hex: 0x09

Float: 9

Bool: 0 1

Binary: 09 1

Bit Size: ○ 1 [✓ ⦿ 8] ○ 16 ○ 32 ○ 64 ○ ?

Figure 37: Set device variable without PLC link

10.4.1 Automatic network setup

The TwinCAT System Manger provides a comfortable master setup.

a. **TwinCAT 2**: Open a new System Manager configuration and scan the network for new devices (Figure 38).

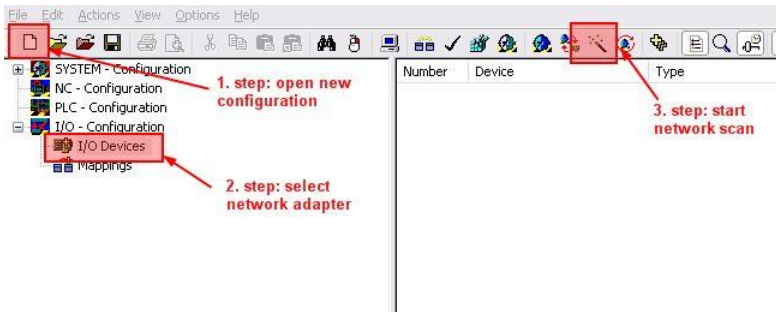

File Edit Actions View Options Help
SYSTEM - Configuration
NC - Configuration
PLC - Configuration
I/O - Configuration
I/O Devices
Mappings
Number
Device
Type
1. step: open new configuration
2. step: select network adapter
3. step: start network scan

Figure 38: Scan for new EtherCAT devices with TwinCAT 2

b. **TwinCAT 3**: Open the Visual Studio shell, create a new TwinCAT project and scan the network for new devices (Figure 27).

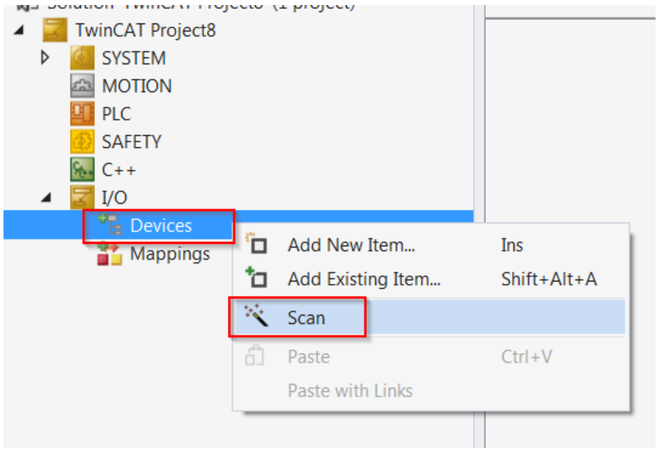


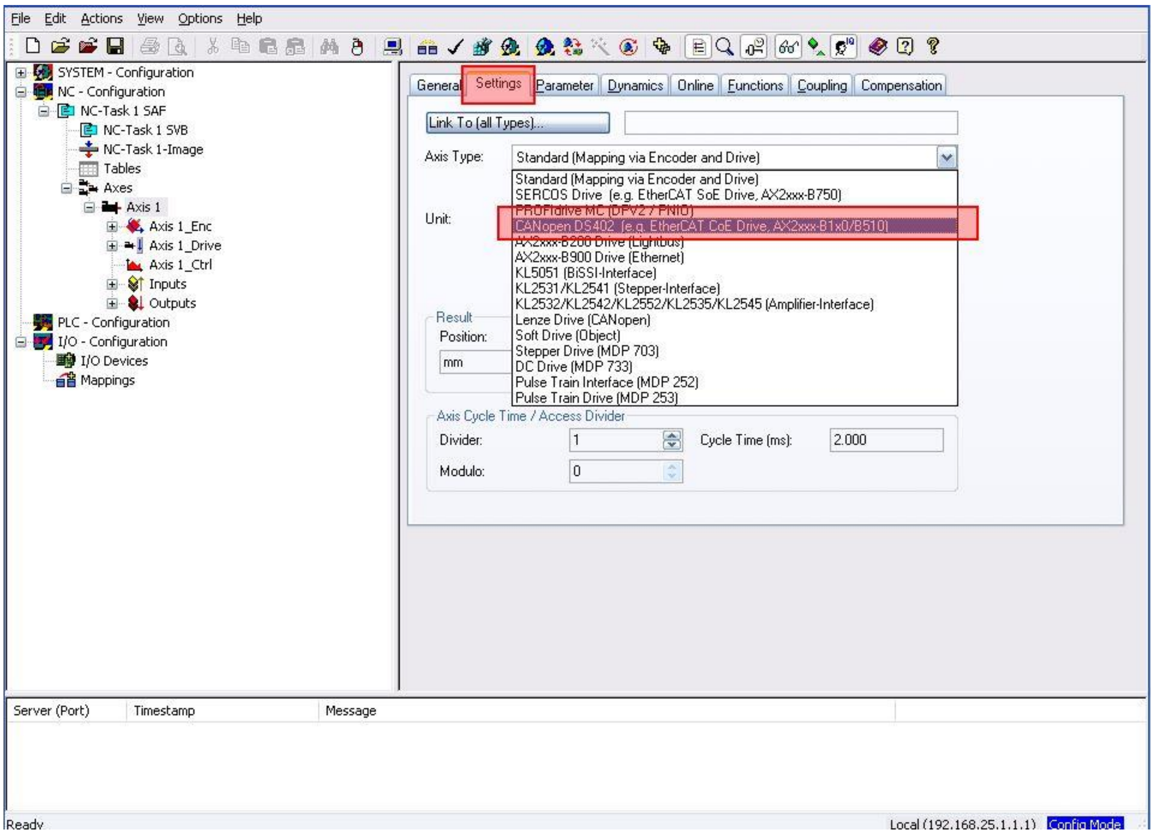
Figure 39: Scan for new EtherCAT devices with TwinCAT 3

After the network scan is complete a message box appears with a notification that an EtherCAT drive was found. If the this message is acknowledged with “Yes” the System Manager will automatically create an NC task with the correct process data mapping.

10.4.2 Manual network setup

First add a NC task including a CiA402 Axis to the NC configuration.

a. **TwinCAT 2** : Add NC task ->Add continuous Axis -> set Axis type to “CANopen DS402” (see Figure 40).



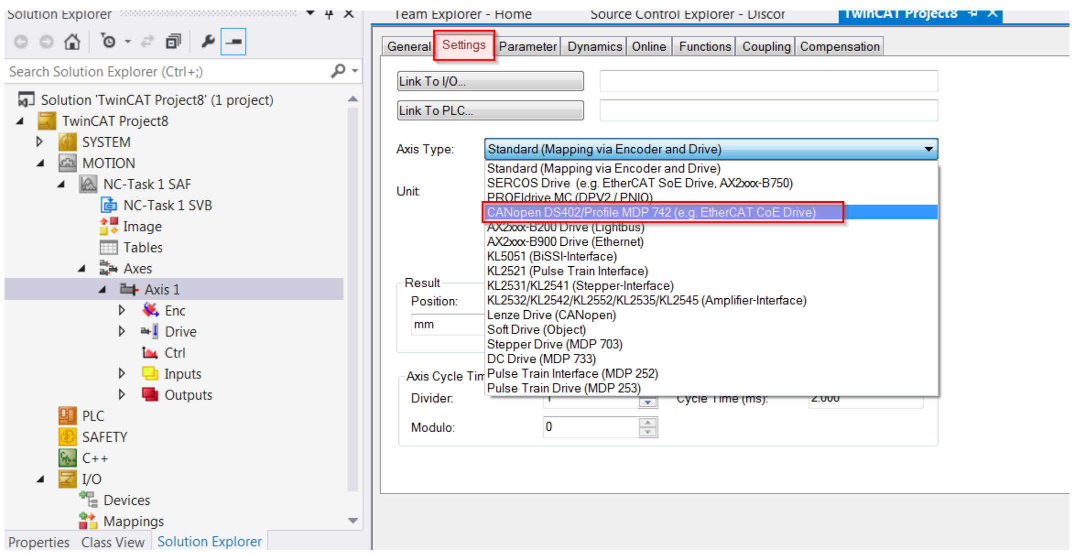
Axis Type: Standard (Mapping via Encoder and Drive)

Standard (Mapping via Encoder and Drive)
SERCOS Drive (e.g. EtherCAT SoE Drive, AX2xxx-B750)
PROFIdrive MC (DPV2 / PNIO)
CANopen DS402 (e.g. EtherCAT CoE Drive, AX2xxx-B1x0/B510)
AX2xxx-B200 Drive (Lightbus)
AX2xxx-B900 Drive (Ethernet)
KL5051 (BiSSI-Interface)
KL2531/KL2541 (Stepper-Interface)
KL2532/KL2542/KL2552/KL2535/KL2545 (Amplifier-Interface)
Lenze Drive (CANopen)
Soft Drive (Object)
Stepper Drive (MDP 703)
DC Drive (MDP 733)
Pulse Train Interface (MDP 252)
Pulse Train Drive (MDP 253)

Divider: 1
Cycle Time (ms): 2.000
Modulo: 0

Figure 40: TwinCAT 2 CiA402 axis setup

a. **TwinCAT 3** : Open the context menu of the MOTION TreeItem -> “Add New Item” -> Type “NC/PTP NCI Configuration” -> Open the context menu of the new created “Axes” TreeItem -> “Add New Item” -> Type “Continuous Axis” -> set Axis type to “CANopen DS402” (see Figure 41: TwinCAT 3 CiA402 axis setup).



Solution Explorer

Search Solution Explorer (Ctrl+;)

```
Solution 'TwinCAT Project8' (1 project)
  TwinCAT Project8
    SYSTEM
    MOTION
      NC-Task 1 SAF
        NC-Task 1 SVB
        Image
        Tables
        Axes
          Axis 1
            Enc
            Drive
            Ctrl
            Inputs
            Outputs
    PLC
    SAFETY
    C++
    I/O
      Devices
      Mappings
```

Properties | Class View | Solution Explorer

Team Explorer - Home | Source Control Explorer - Discor | TwinCAT Project8

General | Settings | Parameter | Dynamics | Online | Functions | Coupling | Compensation

Link To I/O...

Link To PLC...

Axis Type: Standard (Mapping via Encoder and Drive)

```
Standard (Mapping via Encoder and Drive)
SERCOS Drive  (e.g. EtherCAT SoE Drive, AX2xxx-B750)
PROFIdrive MC (DPV2 / PNIO)
CANopen DS402/Profile MDP 742 (e.g. EtherCAT CoE Drive)
AX2xxx-B200 Drive (Lightbus)
AX2xxx-B900 Drive (Ethernet)
KL5051 (BiSSI-Interface)
KL2521 (Pulse Train Interface)
KL2531/KL2541 (Stepper-Interface)
KL2532/KL2542/KL2552/KL2535/KL2545 (Amplifier-Interface)
Lenze Drive (CANopen)
Soft Drive (Object)
Stepper Drive (MDP 703)
DC Drive (MDP 733)
Pulse Train Interface (MDP 252)
Pulse Train Drive (MDP 253)
```

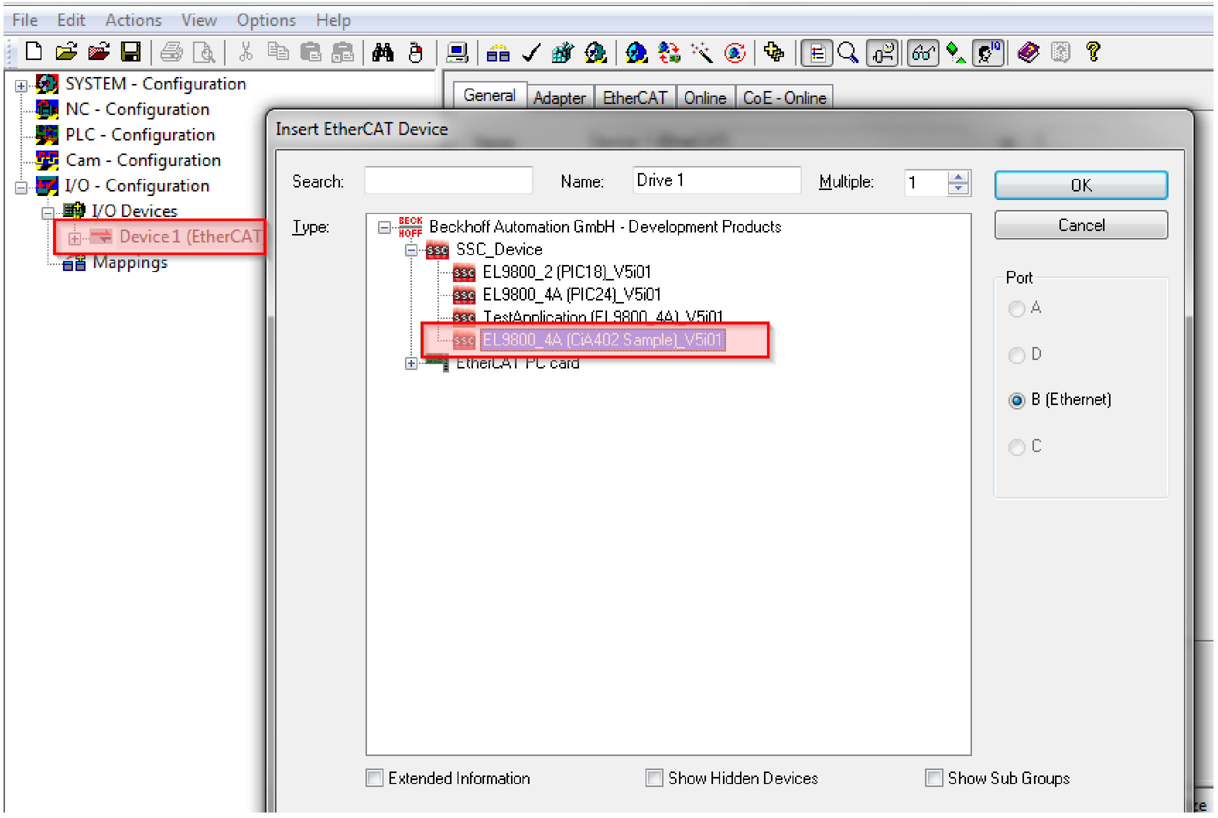
Unit:

Result
Position:
mm

Axis Cycle Tim
Divider: 1   Cycle Time (ms): 2.000
Modulo: 0

Figure 41: TwinCAT 3 CiA402 axis setup

Add a new EtherCAT device and append the CiA402 description (Figure 42).



File | Edit | Actions | View | Options | Help

```
SYSTEM - Configuration
NC - Configuration
PLC - Configuration
Cam - Configuration
I/O - Configuration
  I/O Devices
    Device 1 (EtherCAT)
  Mappings
```

General | Adapter | EtherCAT | Online | CoE - Online

Insert EtherCAT Device

Search: Name: Drive 1   Multiple: 1   OK   Cancel

Type:

```
Beckhoff Automation GmbH - Development Products
  SSC_Device
    EL9800_2 (PIC18)_V5i01
    EL9800_4A (PIC24)_V5i01
    TestApplication (EL9800_4A)_V5i01
    EL9800_4A (CiA402 Sample)_V5i01
  EtherCAT PC card
```

Port: A | D | [✓ B (Ethernet)] | C

Extended Information | Show Hidden Devices | Show Sub Groups

Figure 42: Add CiA402 device

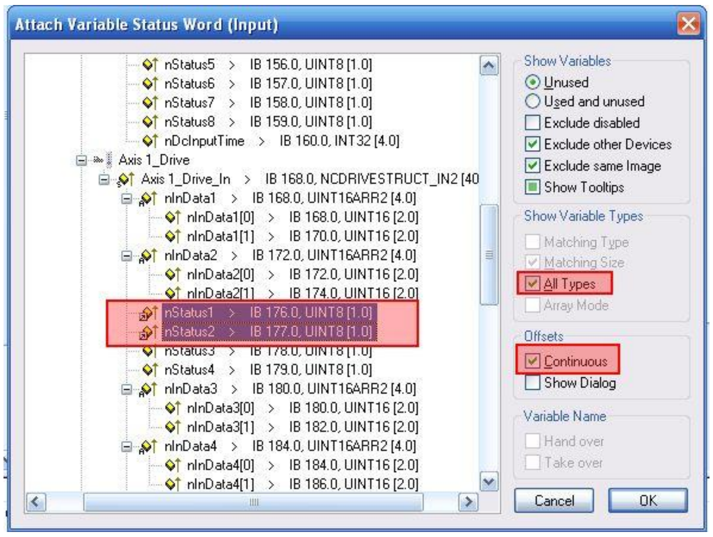
Now the device variables (objects) need to be linked to the axis variables as shown in Table 10.

Table 10: Linking of device and NC variables

object index	Type	variable name	
		device	NC axis
0x6040	output	Controlword	“Drive_Out” -> “nCtrl1” + “nCtrl2”
0x60FF	output	Target velocity	“Drive_Out” -> “nOutData2”
0x6041	input	Statusword	“Drive_In” -> ”nStatus1” + “nStatus2”

object index	Type	variable name	
		device	NC axis
0x6064	input	Actual position	“Enc_In” -> “nInData1”

For the Stausword and Controlword continues process data mapping is required. This can be performed in the linking window (eg. Statusword link window Figure 43). Enable “All Types”, “Continuous” and select the desired variables. TwinCAT will map “nStatus1” to the low byte and “nStatus2” to the high byte of the Statusword.


Attach Variable Status Word (Input)

```
nStatus5      >  IB 156.0, UINT8 [1.0]
nStatus6      >  IB 157.0, UINT8 [1.0]
nStatus7      >  IB 158.0, UINT8 [1.0]
nStatus8      >  IB 159.0, UINT8 [1.0]
nDcInputTime  >  IB 160.0, INT32 [4.0]
Axis 1_Drive
  Axis 1_Drive_In  >  IB 168.0, NCDRIVESTRUCT_IN2 [40
    nInData1     >  IB 168.0, UINT16ARR2 [4.0]
      nInData1[0]  >  IB 168.0, UINT16 [2.0]
      nInData1[1]  >  IB 170.0, UINT16 [2.0]
    nInData2     >  IB 172.0, UINT16ARR2 [4.0]
      nInData2[0]  >  IB 172.0, UINT16 [2.0]
      nInData2[1]  >  IB 174.0, UINT16 [2.0]
    nStatus1     >  IB 176.0, UINT8 [1.0]
    nStatus2     >  IB 177.0, UINT8 [1.0]
    nStatus3     >  IB 178.0, UINT8 [1.0]
    nStatus4     >  IB 179.0, UINT8 [1.0]
    nInData3     >  IB 180.0, UINT16ARR2 [4.0]
      nInData3[0]  >  IB 180.0, UINT16 [2.0]
      nInData3[1]  >  IB 182.0, UINT16 [2.0]
    nInData4     >  IB 184.0, UINT16ARR2 [4.0]
      nInData4[0]  >  IB 184.0, UINT16 [2.0]
      nInData4[1]  >  IB 186.0, UINT16 [2.0]
```

Show Variables: [✓ Unused] / Used and unused; Exclude disabled ☐; Exclude other Devices ✓; Exclude same Image ✓; Show Tooltips 🟩

Show Variable Types: Matching Type ☐; Matching Size ✓; All Types ✓; Array Mode ☐

Offsets: Continuous ✓; Show Dialog ☐

Variable Name: Hand over ☐; Take over ☐

Figure 43: Link multiple variables

10.4.3 NC parameter setup

It is required to setup the encoder and velocity output scaling in the NC-task of the EtherCAT master according to the drive parameters. The sample implementation not supports user defined factor group objects so the default units are used.

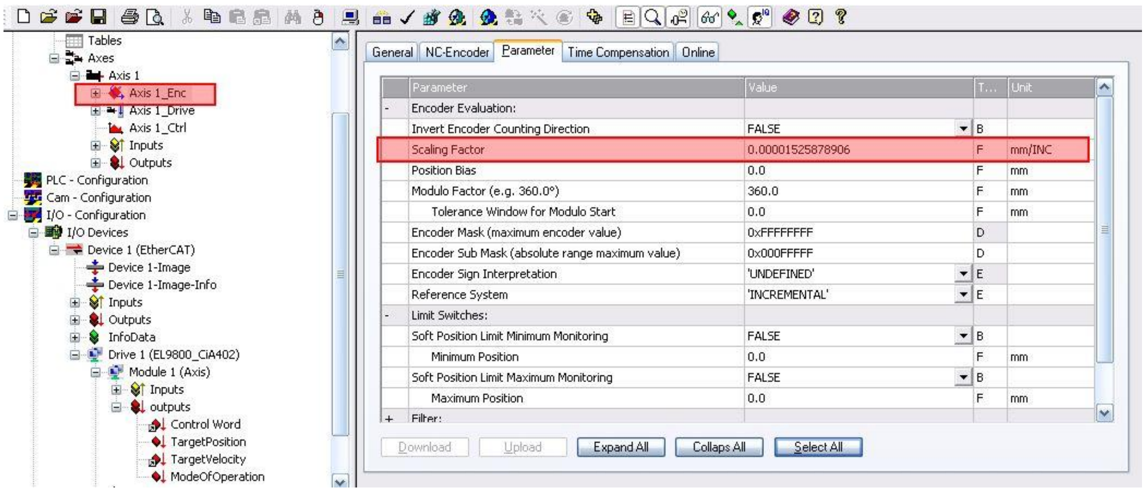
- Position unit: inc
- velocity unit: inc/s
- Encoder resolution: 2^16 inc/rev

If a non-predefined drive is used two basic information are required, the **target velocity value for 1rev/min** (=> target velocity resolution) and the **encoder resolution**.

The encoder resolution defined as 2^16 inc/rev and if 1 rev is equal to 1mm the encoder scaling factor [mm/inc] is 0.0000152588 (Figure 44).

Note: In TwinCAT 3 the parameter is called “Scaling Factor Numerator”.

Encoder scaling factor formula: enc.scaling = (mm/rev)/encoder resolution



- Tables
- Axes
  - Axis 1
    - Axis 1_Enc
    - Axis 1_Drive
    - Axis 1_Ctrl
    - Inputs
    - Outputs
- PLC - Configuration
- Cam - Configuration
- I/O - Configuration
  - I/O Devices
    - Device 1 (EtherCAT)
      - Device 1-Image
      - Device 1-Image-Info
      - Inputs
      - Outputs
      - InfoData
      - Drive 1 (EL9800_CiA402)
        - Module 1 (Axis)
          - Inputs
          - outputs
            - Control Word
            - TargetPosition
            - TargetVelocity
            - ModeOfOperation

General | NC-Encoder | Parameter | Time Compensation | Online

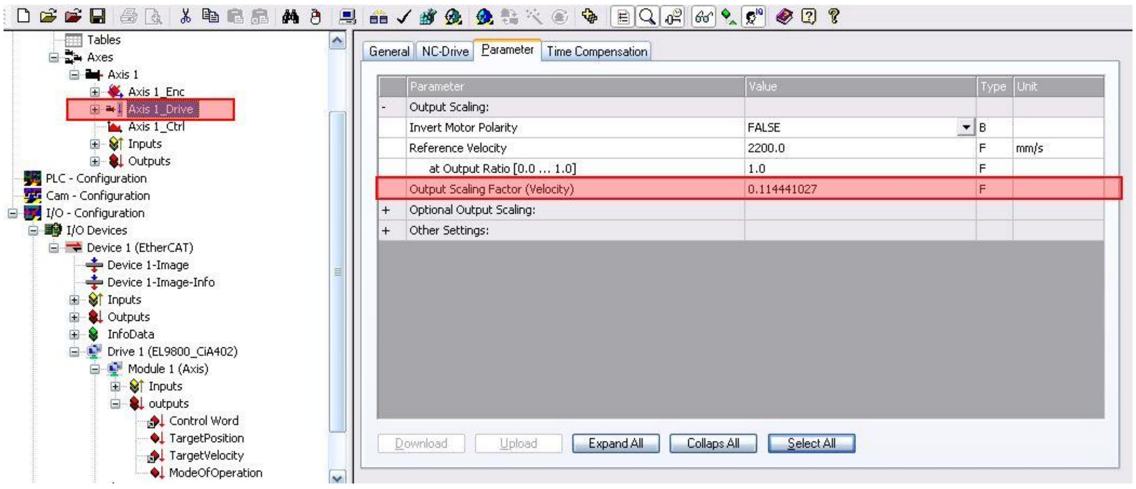
	Parameter	Value	T...	Unit
-	Encoder Evaluation:			
	Invert Encoder Counting Direction	FALSE	B	
	Scaling Factor	0.00001525878906	F	mm/INC
	Position Bias	0.0	F	mm
	Modulo Factor (e.g. 360.0°)	360.0	F	mm
	Tolerance Window for Modulo Start	0.0	F	mm
	Encoder Mask (maximum encoder value)	0xFFFFFFFF	D	
	Encoder Sub Mask (absolute range maximum value)	0x000FFFFF	D	
	Encoder Sign Interpretation	'UNDEFINED'	E	
	Reference System	'INCREMENTAL'	E	
-	Limit Switches:			
	Soft Position Limit Minimum Monitoring	FALSE	B	
	Minimum Position	0.0	F	mm
	Soft Position Limit Maximum Monitoring	FALSE	B	
	Maximum Position	0.0	F	mm
+	Filter:			

Download | Upload | Expand All | Collaps All | Select All

Figure 44: Encoder scaling

The velocity output scaling is calculated with the following formula:
velo.scaling = (2^20 / encoder resolution) * (velo resolution / 139,81)

The velocity resolution [inc/(1rev/min)] is the numerical increment if 1 rev/min is desired. In this case the ratio is 1 so the velocity scaling factor is 0.114441027(Figure 45).



- Tables
- Axes
  - Axis 1
    - Axis 1_Enc
    - Axis 1_Drive
    - Axis 1_Ctrl
    - Inputs
    - Outputs
- PLC - Configuration
- Cam - Configuration
- I/O - Configuration
  - I/O Devices
    - Device 1 (EtherCAT)
      - Device 1-Image
      - Device 1-Image-Info
      - Inputs
      - Outputs
      - InfoData
      - Drive 1 (EL9800_CiA402)
        - Module 1 (Axis)
          - Inputs
          - outputs
            - Control Word
            - TargetPosition
            - TargetVelocity
            - ModeOfOperation

General | NC-Drive | Parameter | Time Compensation

	Parameter	Value	Type	Unit
-	Output Scaling:			
	Invert Motor Polarity	FALSE	B	
	Reference Velocity	2200.0	F	mm/s
	at Output Ratio [0.0 ... 1.0]	1.0	F	
	Output Scaling Factor (Velocity)	0.114441027	F	
+	Optional Output Scaling:			
+	Other Settings:			

Download | Upload | Expand All | Collaps All | Select All

Figure 45: Velocity scaling

11 TestApplication

The test application is a specific slave stack which provides most of the specified EtherCAT slave features and also a mechanism to generate a slave behavior (also behavior which is not conform to the standard). This may be used to check master behavior with incorrect slave behavior.

This chapter is dealing with the possible configurations. The possible (mis)behaviors are organized within CoE objects in the index range from 0x2000 to 0x2FFD (Table 11 and Table 12).

In object 0x8000 the stack configuration is listed (SDO info need to be supported by EtherCAT master).

A release build of the test application for the EL9800 EtherCAT Evaluation board is located in "SSC_Vxixx/hex". To create new test application slave files select the test application configuration in the SSC Tool.

Table 11: Test Object

Attribute	Value
Index	0x2000 to 0x2FFD
Name	Test object
Object Code	RECORD
Max SubIndex	1-255

Table 12: Test Object Entry

Sub-Index	Description	Data Type	Access	PDO Mapping	Description / Default value	
n (equal for every test)	Control/Counter	UNSIGNED16	RW/R	No	Control the test behavior	
					Bit0	enable/disable the test 0: Test disabled 1: Test enabled
					Bit1 -7	Reserved for future use
					Bit8-15	Counter (indicates the number of test executions)

11.1 Slave Behavior Control

Three possibilities are available to control the slave behavior either updating the enable/disable bit of the test object directly (Table 12: Test Object Entry), or via the Test Control object (Chapter 11.1.1) or by updating the ESC register 0xF80:0xF83 (Chapter 11.1.2).

11.1.1 Test Control Object

The Test Control object structure (Table 13 and Table 14) is similar to the PDO mapping objects. Every Subindex (entry) of the test control object maps an enable/disable function (Bit 0) to a physical digital input of the slave device.

If the application is compiled for the EL9800_4 EtherCAT Evaluation Kit the control object contains 7 entries (SI1-7) which are mapped to the switches 2 to 8 (switch 1 is a global test function enable switch). If the stack is not compiled for the EL9800 the control element contains 16 Entries which are mapped to the GPO register (0xF10:0xF11).

Table 13: Test Control Object

Attribute	Value
Index	0x2FFF
Name	Test control object

Attribute	Value
Object Code	ARRAY
Max SubIndex	16 (7if build for EL9800)

Table 14: Test Control Object Entries

<table>
<tr><th>Sub-Index</th><th>Description</th><th>Data Type</th><th>Access</th><th>PDO Mapping</th><th colspan="2">Description / Default value</th></tr>
<tr><td rowspan="4">1 – Max SubIndex (see Table 13)</td><td rowspan="4">Linked test object entry</td><td rowspan="4">UNSIGNED32</td><td rowspan="4">RW</td><td rowspan="4">No</td><td colspan="2">Linked test object entry</td></tr>
<tr><td>Bit0 – 7</td><td>Reserved for future use</td></tr>
<tr><td>Bit8 - 15</td><td>Subindex of the test object entry</td></tr>
<tr><td>Bit16-32</td><td>Index of the test object</td></tr>
</table>

11.1.2 User RAM 0xF80:0xF83

The master can write the object index and subindex of the behavior to be activated to the register (Table 15: Test Application | ESC Register 0xF80:0xF83). The value is read by the application on a state trigger from INIT to any (also INIT to INIT), if the behavior is accepted the first bit in 0xF83 is set.

Table 15: Test Application | ESC Register 0xF80:0xF83

Bit	Description	Purpose
0:15	Object Index	Updated by the master
16:23	Subindex	Updated by the master
24	1 : behavior active	Shall be set to 0 by the master if a new index/subindex was written. Is set to 1 by the slave application
32:31	Reserved for future use	

11.2 ESM Tests (0x2000 – 0x200F)

Table 16: Test Object 0x2000 (ESM Group 1)

Sub-Index	Description	Purpose
1	Invalid state transition from INIT to PreOP AL status Code 0x16 (Invalid Mailbox)	
2	Invalid state transition from PreOP to SafeOP AL status Code 0x1D (Invalid Output SyncManager config)	
3	Invalid state transition from PreOP to SafeOP AL status Code 0x1E (Invalid Input SyncManager config)	
4	Do not unlock the SM3 (process data input SyncManager) buffer during the transition from PreOP to SafeOP.	Check if the Master starts the process data communication without initial input process data.

5	Acknowledge state requests not directly. ECAT_StateChange() is used.	

11.3 Mailbox Tests (0x2010 – 0x201F)

Table 17: Test Object 0x2010 (Mailbox Group 1)

Sub-Index	Description	Purpose
1	Check if the master mailbox counter is always incremented by 1. If not a mailbox error will be returned.	Check if the EtherCAT master sends the correct mailbox counter sequence.
2	Change the slave mailbox counter in alternating order. The mailbox counter may also have the value 0 after it was incremented.	An EtherCAT master should also handle a mailbox counter sequence unequal an increment by one.

11.4 CoE Tests (0x2020 – 0x202F)

Table 18: Test Object 0x2020 (CoE Group 1)

Sub-Index	Description	Purpose
1	On SDO upload and SDO Info List request a maximum mailbox size of 16Bytes is used.	Decouple physical mailbox size from mailbox data length.
2	Create diagnosis message on every state change.	
3	Create diagnosis message with every application cycle.	
4	“simulate” huge object dictionary. The number of objects is specified by “DUMMY_OD_LENGTH” (default 1000). All objects have the index 0x1000	This behavior is used to test the List segmentation handling of the master and SSC.
5	Return on SDO upload with complete access always the full object data based on MAX Subindex (Value of SI0 is ignored)	
6	Send an emergency on any SDO request in SafeOP	
7	Pending SDO response on a SDO upload or download on 0x3006.0. The request will be answered when a FoE read request for file “UnlockSdoResp” is received or in case that the mailbox queue is not supported on the next received mbx request.	Check correct pending SDO request handling.
8	Send an EoE ARP on all SDO access (upload/info/download) on 0x1009	
9	Send an invalid mailbox data on all SDO access (upload/info/download) on 0x1009	

11.5 FoE Tests (0x2030 – 0x203F)

Table 19: Test Object 0x2030 (FoE Group 1)

Sub-Index	Description	Purpose
1	Return an FoE Busy on a FoE Read request	

11.6 Generic Objects

The objects described in this chapter are used to test the correct SDO handling by the slave and the master. Table 20: Generic Objects includes all defined objects.

Table 20: Generic Objects

Index / Subindex	Daftype / Code	Access	Description	Purpose
0x3001	RECORD / REC	RW		
SI1	REAL32		Default value: 0xBABABABA	
SI2	REAL64		Default value: 0xBABABABABABABABA	
SI3	UINT64		Default value: 0xBABABABABABABABA	
SI4	INT64		Default value: 0xBABABABABABABABA	
0x3002	UINT32 / VAR	RW	Default value: 0xBABABABA	
0x3003	RECORD / REC		Includes base dataypes less or equal 1Byte.	
SI1	BOOLEAN	RW	Default value: TRUE	
SI2	BIT1	RW	Default value:0x0	
SI3	BIT2	RW	Default value:0x3	
SI4	BIT3	RW	Default value:0x5	
SI5	1BIT Align			Next entry shall start at an Byte border
SI6	BIT4	Read; Write in Op and PreOP	Default value:0xA	
SI7	4BIT Align			Next entry shall start at an Byte border
SI8	BIT5	RW	Default value:0x1A	
SI9	3BIT Align			Next entry shall start at an Byte border
SI10	BIT6	RW	Default value:0x2A	

SI11	2BIT Align			Next entry shall start at an Byte border
SI12	BIT7	RW	Default value:0x6A	
SI13	1BIT Align			Next entry shall start at an Byte border
SI14	BIT8	Read; Write in PreOP	Default value:0xFF	
SI15	UINT8	Read; Write in SafeOP	Default value:0xAA	
SI16	INT8	Read; Write in OP	Default value:0xBB	
0x3004	RECORD / REC		Object to test alignment, empty entries and several access rights	
SI1	UINT16	RO	Default value:0x1122	
SI2	UINT16	RW	Default value:0x3344	
SI3	UINT16	WO	Default value:0x5566	
SI4	BIT8	Write; Read in PreOP	Default value:0x77	Datatype BIT8 is used because to “group” them into one 16Bit block (in case of an 16 or 32 Bit Controller the Alignment entry and Bit types are based on unsigned short)
SI5	8Bit Align			
SI6	Empty			
SI7	8Bit Align			
SI8	UINT8	RO	Default value:0x88	
SI9	BIT2	WO	Default value:0x1	
SI10	BIT2	Write; Read in SafeOP	Default value:0x2	
SI11	2BIT Align			
SI12	BIT2	RO	Default value:0x3	
SI13	BOOLEAN	RW	Default value TRUE	
SI14	BIT7	Write; Read in OP	Default value: 0	A single access to this entry will always return the SDO Abort Code 0x08000021 (Data cannot be read or stored because of local control)
0x3005	RECORD / REC		Uses two enum definitions: 0x800: Signed/unsigned presentation 0x801: Boolean	Generic enum test and test access to byte aligned enum definitions
SI1	0x800	RW	Default value : “signed presentation”	

SI2	0x801	RW	Default Value: “True”	
SI3	10BIT Align			
SI4	0x802	RW	Default Value “Two Hundred”	
0x3006	OCTET_STRING / VAR	RW	The object size is 349 Byte. If a 128 Bytes mailbox is used the object is transmitted with one complete and two segmented services minus one Byte. Default value: Each Byte is incremented by one (starts with 0x00)	This object is used to test the mailbox unlock mechanism within the slave stack and the correct segmented handling by the master.
0x3007	BIT3/ARRAY	RW	BIT3 array with 5 elements	
0x3008	RECORD / REC		Includes set of Array base data types (e.g. BITARR32)	
SI1	OCTET_STRING	RW	UINT8 Array with four elements	
SI2	UNICODE_STRING	RW	UINT16 Array with two elements	
SI3	ARRAY_OF_SINT	RW	INT8 Array with four elements	
SI4	ARRAY_OF_INT	RW	INT16 Array with two elements	
SI5	ARRAY_OF_DINT	RW	INT32 Array with one element	
SI6	ARRAY_OF_UDINT	RW	UINT32 Array with one element	
SI7	BITARR32	RW	32Bit Array	
SI8	BITARR16	RW	16BitArray	
SI8	BITARR8	RW	8BitArray	
0x3009	OCTET_STRING / ARRAY		Huge Array Object.	This object is used to test huge object handling in the master
SI1 – 254	OCTET_STRING	RW	The first WORD of SI1 contains the Bitlength of each entry. The value can also be updated by single WORD access to SI1 all other write access will be ignored (no SDO Abort returned). The uploaded data will always be 0xBA.	
0x300A	RECORD / REC		Huge Record Object Within the SSC it is handled equal to	This object is used to test huge object handling in the master

			0x3009 only the object code is changed.	
SI1 – 254	OCTET_STRING	RW	The first WORD of SI1 contains the Bitlength of each entry. The value can also be updated by single WORD access to SI1 all other write access will be ignored (no SDO Abort returned). The uploaded data will always be 0xBA.	
0x300B	RECORD / REC		Byte Arrays with odd word length	Test correct complete access handling of byte array entries with odd word length.
SI1	OCTET_STRING	RW	Default value : “12345”	
SI2	UINT8	RO	Default value : 0x66	
SI3	OCTED_STRING	RW	Default value : 0x77 – 0xBB	
SI4	UINT8	RW	Default value : 0xCC	
0x300C	VAR		Max entry size object	Test behavior if the entry size is > 65535
0x300D	RECORD / REC		Slave-to-Slave test object	Test the Slave - to- Slave communication by sending an SDO upload on 0x1018.2 to a specific slave
SI1	UINT16	RW	Destination slave address	EtherCAT address of the destination slave.
SI2	UINT8	RW	Command	If 1 is written an SDO upload on 0x1018.2 is generated.
SI3	UINT8	RO	Status	1 : The SDO upload is generated 2 : The SDO upload response was received and written to SI4
SI4	UINT32	RO	IdentValue	Value of 0x1018.2 from the slave addressed in SI1.
0x300E	RECORD / REC		si0_rw sin_ro test object	
SI1 – 3	UINT16	RO		
0x300F	UINT16 / REC		si0_rw sin_ro test object	
SI1 – 3	UINT16	RO		
0x3010	RECORD / REC		si0_ro sin_wo test object	
SI1 - 3	UINT16	WO		
0x3012	RECORD / REC			Record with SI0 = 0

SI1 - 3		RO		
0x3013	BITARR32/VAR	RW		
0x3014	BITARR16/VAR	RW		
0x3015	BITARR8/VAR	RW		
0x3016	RECORD / REC	RW	empty record object	
0x3017	OCTED_STRING / VAR	RW	EoE Send Data	the written data is send via EoE to the master back (only supported if MAILBOX QUEUE and dynamic memory allocation is available)

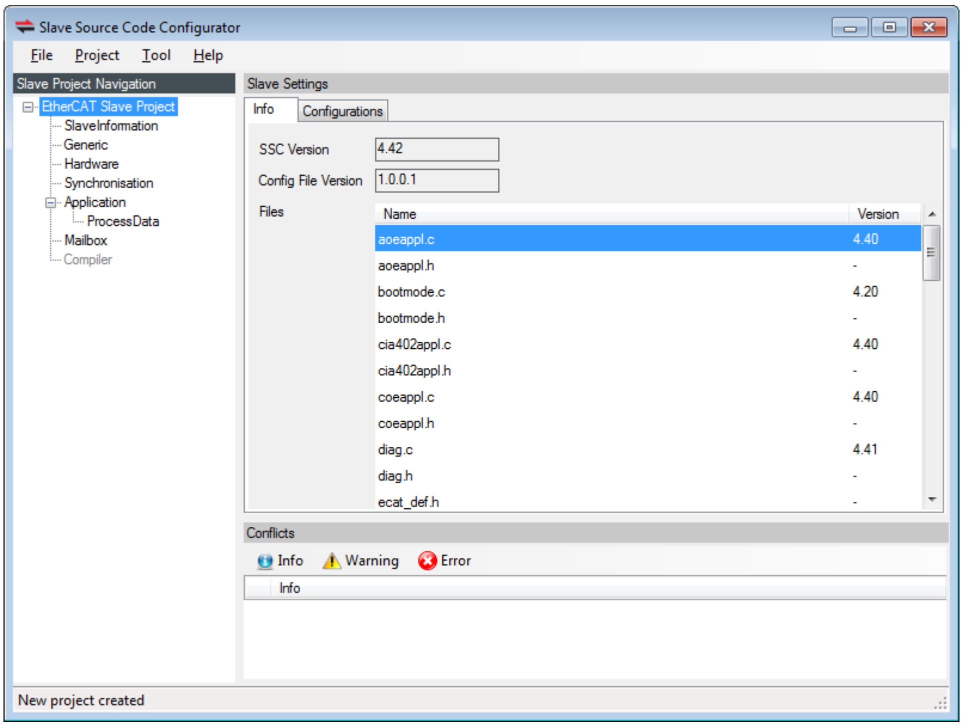
12 SSC Tool

The Slave Stack Code Tool allows creating new slave files depending on user specific requirements and settings.
List of slave files:

- C source code files
- Source code documentation (optional)
- Device Description (ESI) (optional)

Supported OS: Windows XP, Vista, 7 (32bit)
Required Framework: .NET (4.0)

Two new file extensions are registered: SSC Configuration File (*.escfg) and Slave Project File (*.esp). The configuration file is provided with each SSC version and includes all settings and information about the code. The Slave Project File is created by the configurator to save a slave project.
The main user interface (Figure 46: Configurator Main User Interface) is structured in the tool bar (*File*, *Project*, *Tool* and *Help*) above and 3 separated windows (*Slave Project Navigation*, *Slave Settings* and *Conflicts*).



SSC Version: 4.42
Config File Version: 1.0.0.1
Files

Name	Version
aoeappl.c	4.40
aoeappl.h	-
bootmode.c	4.20
bootmode.h	-
cia402appl.c	4.40
cia402appl.h	-
coeappl.c	4.40
coeappl.h	-
diag.c	4.41
diag.h	-
ecat_def.h	-

Figure 46: Configurator Main User Interface

The following chapters describe the elements in more detail.

12.1 Default Startup Dialogs

[*Usage Information*]
SSC tool usage information which need to be acknowledged before start working.

[*Vendor Information*]
Dialog to enter your Vendor Information including Vendor ID and Vendor name. These Information will be added automatically to a new slave project. This information can also be added via the Options dialog.

[*Run Wizard*]
Start the project wizard to create a new slave project.

12.2 Main User Interface Elements

12.2.1 Tool Bar

12.2.1.1 File

The file menu (Figure 47: Configurator File Menu) contains the project file operations.

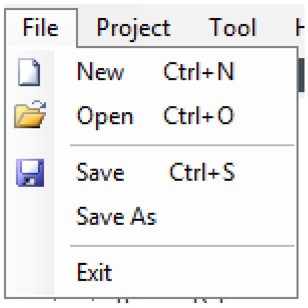
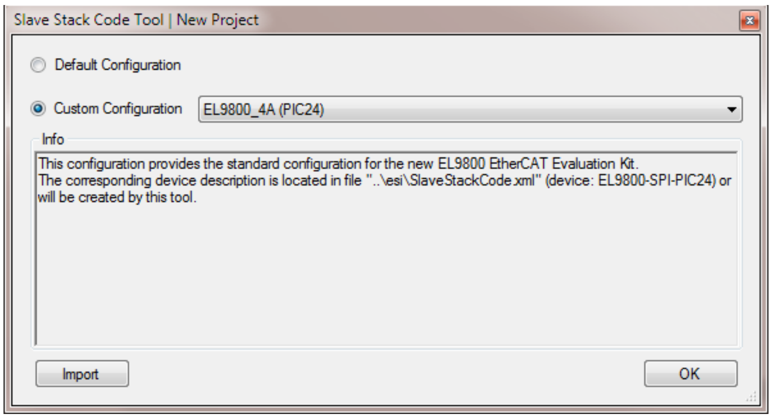


Figure 47: Configurator File Menu

[*New*]
Create a new slave project based on the local SSC files. The project can either be created on the default configuration or a custom configuration (Figure 48: Create New Project). To import third party configurations see 12.6.



Slave Stack Code Tool | New Project

Default Configuration

[✓ Custom Configuration] EL9800_4A (PIC24)

Info

This configuration provides the standard configuration for the new EL9800 EtherCAT Evaluation Kit.
The corresponding device description is located in file "..\esi\SlaveStackCode.xml" (device: EL9800-SPI-PIC24) or will be created by this tool.

Import OK

Figure 48: Create New Project

[*Open*]
Open an existing project file.

[*Save*]
Save the actual settings to the current project file (if no project file was created before a file browser dialog appears to create a new file).

[*Save As*]
Save the actual settings to a new project file.

[*Exit*]
Close current session.

12.2.1.2 Project

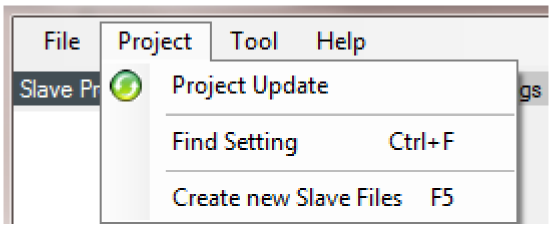
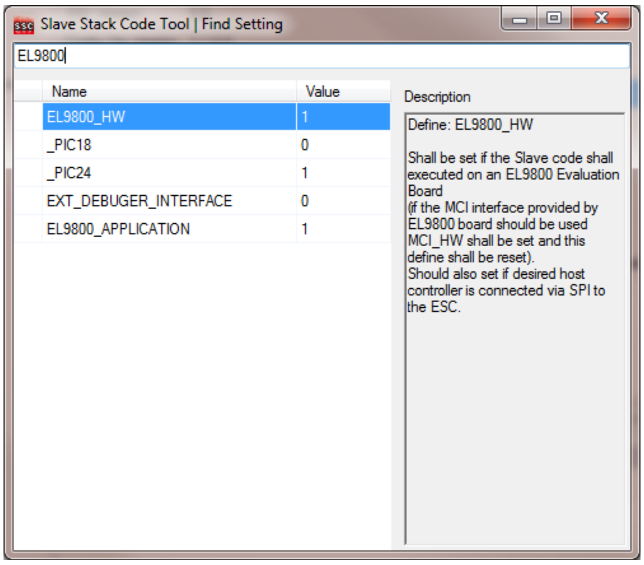


Figure 49: Configurator Project Menu

[*Project Update*]
Check for new Slave Stack Code version and update the current project. For further information see chapter 12.5.

[*Find Setting*]
Open a dialog to find defines.



EL9800

Name	Value
EL9800_HW	1
_PIC18	0
_PIC24	1
EXT_DEBUGER_INTERFACE	0
EL9800_APPLICATION	1

Define: EL9800_HW

Shall be set if the Slave code shall executed on an EL9800 Evaluation Board
(if the MCI interface provided by EL9800 board should be used MCI_HW shall be set and this define shall be reset).
Should also set if desired host controller is connected via SPI to the ESC.

Figure 50: Find Setting Dialog

[*Create new Slave Files*]
Open a dialog to create new slave files depending on the actual settings.

12.2.1.3 Tool

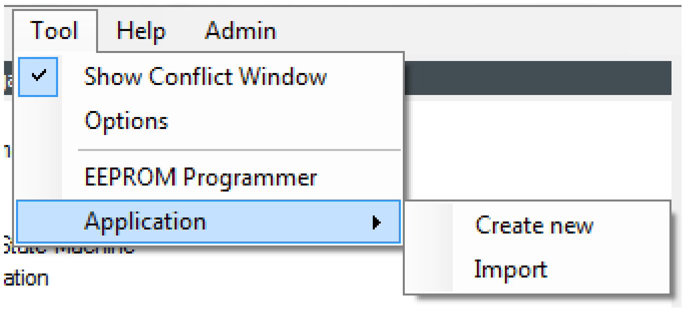


Figure 51: Tool Menu

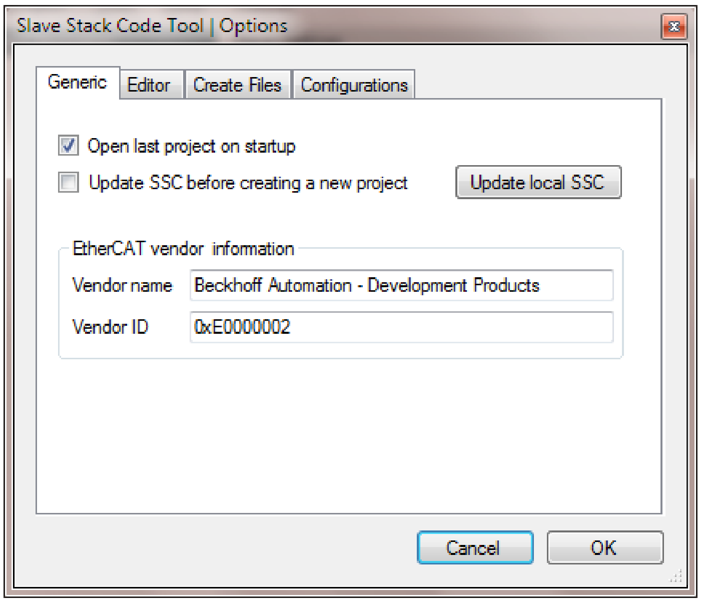
[*Show Conflict Window*]
Hide or show the conflict window.

[*Options*]
Open the options dialog (see Figure 52: Tool Options).

[EEPROM Programmer]
Open the EEPROM Programmer tool. This tool can be used to create an EEPROM header or binary file or to program the EEPROM of EtherCAT slaves. For further details see 14.2EEPROM Programm.

[Application->Create new]
Creates a new Excel based application definition file. After Excel (or the corresponding *.xlsx Editor is closed) the application will be applied to the slave project.

[Application->Import]
Imports a new slave application. The supported file types are described in chapter 13.


Slave Stack Code Tool | Options

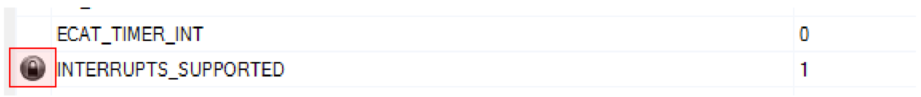
- [✓] Open last project on startup
- [ ] Update SSC before creating a new project

EtherCAT vendor information

Vendor name	Beckhoff Automation - Development Products
Vendor ID	0xE0000002

Figure 52: Tool Options

- Generic
  - [*Open last project on startup*]
    The last slave project is reloaded on the next startup of the tool.
  - [*Update SSC before creating a new project*]
    If this flag is set the Slave Stack Code Tool checks if a new SSC version is available before creating a new project.
    NOTE: Before each project update ([*Project*] -> [*Project Update*]) an update of the local SSC file will be triggered.
    The local SSC files are stored in the application data folder.
  - [*Update local SSC*]
    Update local SSC files.
  - [*Vendor Name*]
    Add your Vendor name here. This information will be added to slave project.
  - [Vendor ID]
    Add your Vendor ID here. This information will be added to the slave project.
    If you don’t have a Vendor ID yet please contact info@ethercat.org.
- Editor
  - [*Show advanced settings*]
    Show also defines which are marked as advanced (e.g. compiler defines)
  - [*Show read only settings*]
    Defines which are marked as read-only are shown (but remain read only). Read only defines are marked with a lock symbol (see Figure 53: Configurator Locked Define).



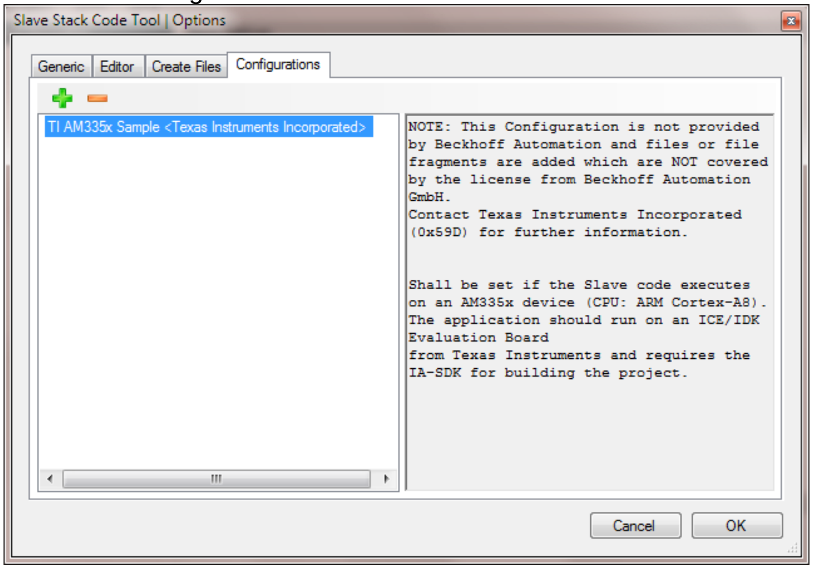
	ECAT_TIMER_INT	0
🔒	INTERRUPTS_SUPPORTED	1

Figure 53: Configurator Locked Define

  - [Block type mismatching setting values]
    If enabled the new values with an invalid type format will be blocked.
  - [Update dependent settings]
    Ignore: dependent defines will not be updated
    ApplyAll: all dependent defines will be updated
    AskUser: a dialog will be displayed if a dependent define has changed.
- Create Files

- [*Add comment if obsolete code was skipped*]
  Specify if a source code comment shall be added when code was deleted in comparison with the default Slave Stack Code.
- [*Create documentation*]
  Create a code documentation based on the previously created source files. This feature requires external tools which are NOT covered by the SSC Beckhoff license agreement! Note the tool specific usage license.
  Basically Doxygen is required. It is possible to use an specific Doxygen configuration file otherwise the default configuration is used which additionally requires GraphViz and HTML Help Workshop.
- [*Use configuration file*]
  Use a user specific doxygen configuration file.
- [*Required Software*]
  Select location of the required software.
- *[Create device description (ESI)]*
  If this option is checked an application specific device description will be cereated.

- Configurations
  In this Options tab the list of custom configurations can be changed. A Configuration contains a define list, files and ESI fragments which are required to run the SSC on a specific platform or to add a new application. A Configuration is described in xml format. Contact EtherCATSSC@beckhoff.com to get the corresponding schema.
  - *[+]*
    Import new configurations.
  - *[-]*
    Remove a configuration from the list.



TI AM335x Sample <Texas Instruments Incorporated>

```
NOTE: This Configuration is not provided
by Beckhoff Automation and files or file
fragments are added which are NOT covered
by the license from Beckhoff Automation
GmbH.
Contact Texas Instruments Incorporated
(0x59D) for further information.


Shall be set if the Slave code executes
on an AM335x device (CPU: ARM Cortex-A8).
The application should run on an ICE/IDK
Evaluation Board
from Texas Instruments and requires the
IA-SDK for building the project.
```

Figure 54: Configurations List

12.2.1.4 Help

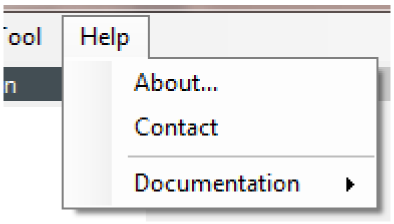


Figure 55: Configurator Help Menu

[*About*]
Show information about the SSC Tool.

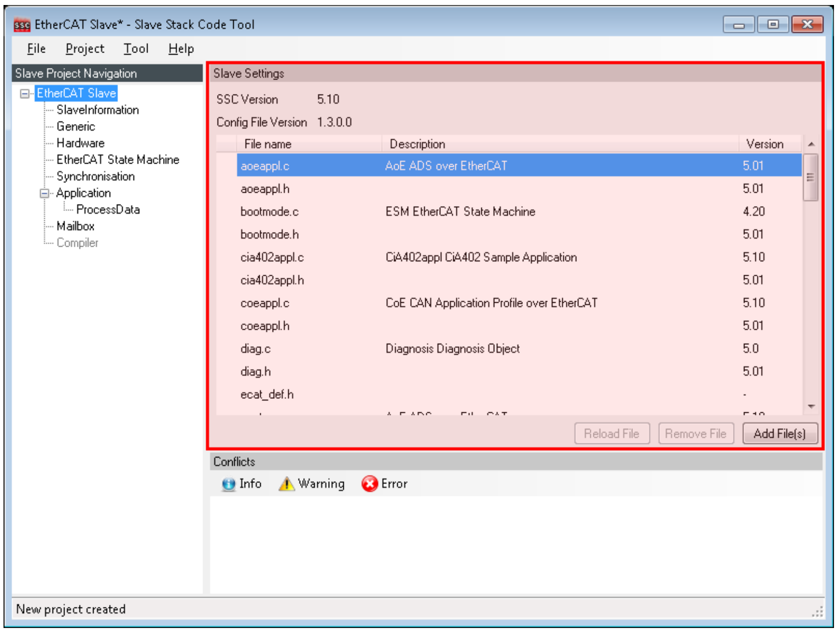
[*Contact*]
Create a new email to EtherCATSSC@beckhoff.com with your standard email client.

[*Documentation*]
List of SSC related documents

12.2.2 Windows

I. [*Slave Project Navigation*]
The *Slave Project Navigation* window lists all kinds of defines which can be configured. Selecting one of the nodes, the corresponding defines are displayed in the *Slave Settings* window. If the project was saved at least once the root node name is equal to the project name. This window also supports Drag & Drop.

[*Slave Settings*]
The information shown in this window depends on the selected node in the *Slave Project Navigation* window.
If the root project node is selected the *SSC Version*, *Config File Version*, a list of all Slave Stack Code files and user files are shown (see Figure 56: Configurator Project Information). The file list within provides a right-click context menu (see Figure 57: Configurator File Context Menu).


EtherCAT Slave* - Slave Stack Code Tool

File Project Tool Help

Slave Project Navigation
- EtherCAT Slave
  - SlaveInformation
  - Generic
  - Hardware
  - EtherCAT State Machine
  - Synchronisation
  - Application
    - ProcessData
  - Mailbox
  - Compiler

Slave Settings

SSC Version 5.10
Config File Version 1.3.0.0

File name	Description	Version
aoeappl.c	AoE ADS over EtherCAT	5.01
aoeappl.h		5.01
bootmode.c	ESM EtherCAT State Machine	4.20
bootmode.h		5.01
cia402appl.c	CiA402appl CiA402 Sample Application	5.10
cia402appl.h		5.01
coeappl.c	CoE CAN Application Profile over EtherCAT	5.10
coeappl.h		5.01
diag.c	Diagnosis Diagnosis Object	5.0
diag.h		5.01
ecat_def.h		-

Reload File Remove File Add File(s)

Conflicts
Info Warning Error

New project created

Figure 56: Configurator Project Information

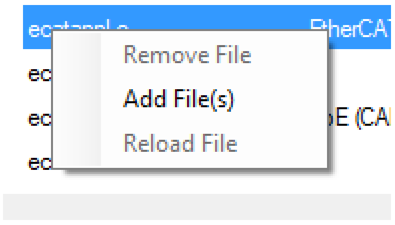


Figure 57: Configurator File Context Menu

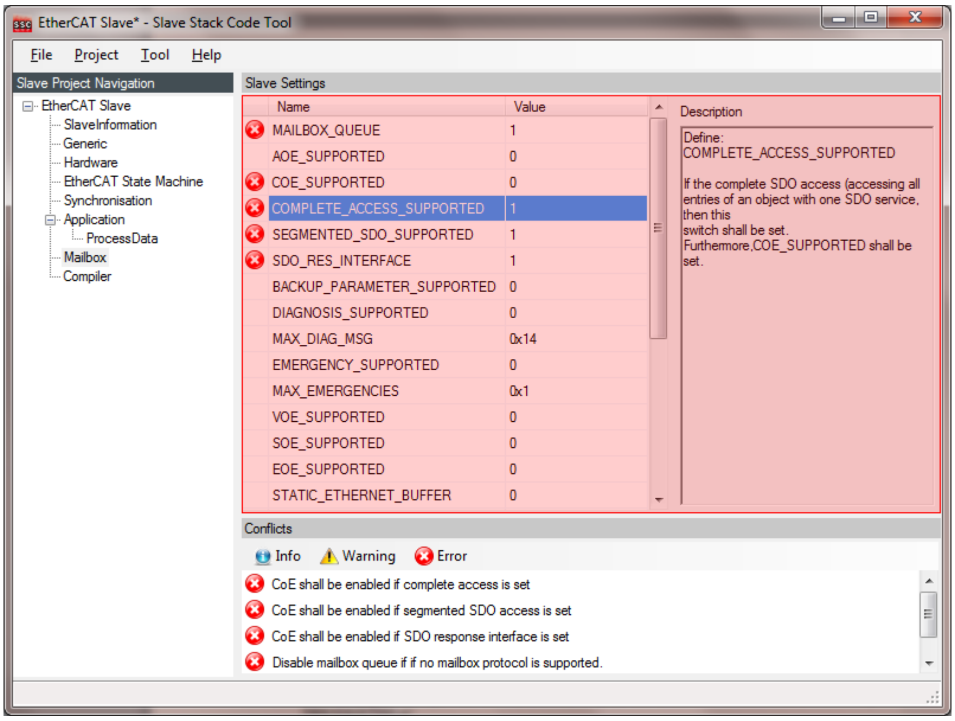
[*Reload File*]
Cached file will be reloaded (only possible for user files).

[*Remove File*]
Remove file from project (only possible for user files).

[*Add File(s)*]
Add one or more files to the project. These files will not evaluated and just copied to the output folder.
If a new hardware access file is add it can be included to the generic files by define "HW_ACCESS_FILE" in the hardware settings (e.g. "#include "myhw.h"").
If a new application file is add also add the reference to "APPLICATION_FILE" (e.g. "#include "myappl.h"").
NOTE: "Advanced Editor settings need to be activated to edit the file reference settings.

Edit File (double click on file)
To Edit a user specific source file double click on the file. The default editor for this file type will be open.

If one of the setting nodes are selected within the *Slave Project Navigation*, the corresponding settings are displayed within the *Slave Settings* window (Figure 58: Configurator Slave Settings).



	Name	Value
⊗	MAILBOX_QUEUE	1
	AOE_SUPPORTED	0
⊗	COE_SUPPORTED	0
⊗	COMPLETE_ACCESS_SUPPORTED	1
⊗	SEGMENTED_SDO_SUPPORTED	1
⊗	SDO_RES_INTERFACE	1
	BACKUP_PARAMETER_SUPPORTED	0
	DIAGNOSIS_SUPPORTED	0
	MAX_DIAG_MSG	0x14
	EMERGENCY_SUPPORTED	0
	MAX_EMERGENCIES	0x1
	VOE_SUPPORTED	0
	SOE_SUPPORTED	0
	EOE_SUPPORTED	0
	STATIC_ETHERNET_BUFFER	0

Description
Define:
COMPLETE_ACCESS_SUPPORTED

If the complete SDO access (accessing all entries of an object with one SDO service, then this switch shall be set.
Furthermore,COE_SUPPORTED shall be set.

⊗ CoE shall be enabled if complete access is set
⊗ CoE shall be enabled if segmented SDO access is set
⊗ CoE shall be enabled if SDO response interface is set
⊗ Disable mailbox queue if if no mailbox protocol is supported.

Figure 58: Configurator Slave Settings

II. Conflict Window
This window displays conflicts of defines. Conflicts are distinguished between errors, warnings and information. Conflicting defines are denoted by the corresponding conflict symbol.
NOTE: Not every combination of defines is checked. So it is up to the user to create a logical configuration.

[*Error*] Indicate that the configurator cannot create a valid slave stack with the actual configuration.
[*Warning*] The defines marked with the warning symbol should be checked before creating new slave files.
[*Info*] Additional information about the current configuration.

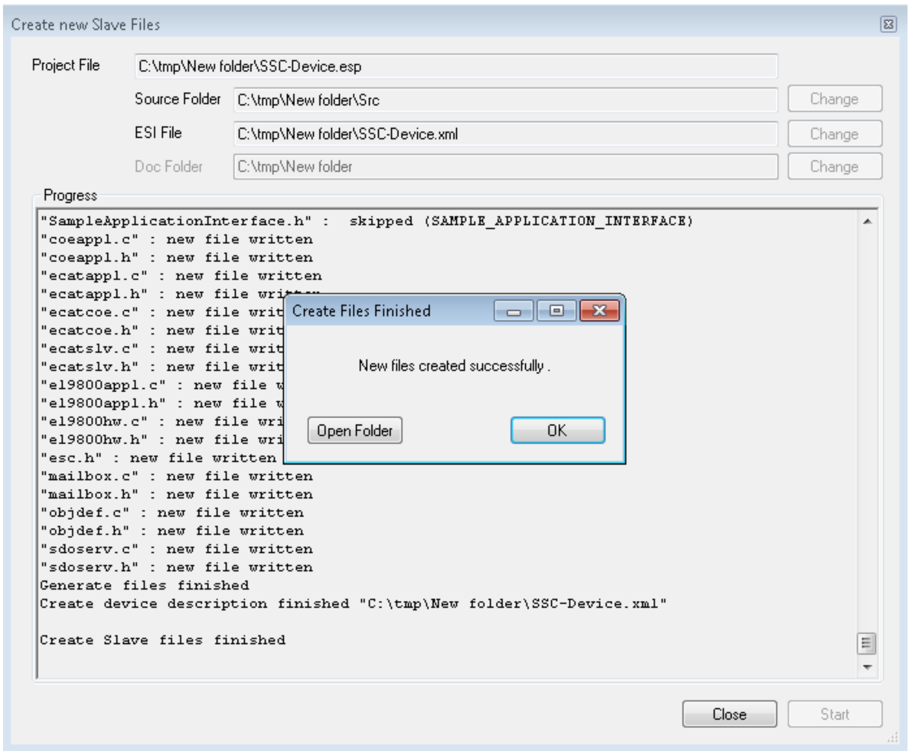
12.3 Create Files

Creating new files is the last step to create a new slave stack. The dialog is opened by selecting [*Project*] -> [*Create new Slave Files*].

a) Select output folder.

b) [*Start*] Start creating new files.

c) Output window dumps progress information.


Create new Slave Files

Project File: C:\tmp\New folder\SSC-Device.esp

Source Folder: C:\tmp\New folder\Src

ESI File: C:\tmp\New folder\SSC-Device.xml

Doc Folder: C:\tmp\New folder

Progress

```
"SampleApplicationInterface.h" :  skipped (SAMPLE_APPLICATION_INTERFACE)
"coeappl.c" : new file written
"coeappl.h" : new file written
"ecatappl.c" : new file written
"ecatappl.h" : new file wri
"ecatcoe.c" : new file writ
"ecatcoe.h" : new file writ
"ecatslv.c" : new file writ
"ecatslv.h" : new file writ
"el9800appl.c" : new file w
"el9800appl.h" : new file w
"el9800hw.c" : new file wri
"el9800hw.h" : new file wri
"esc.h" : new file written
"mailbox.c" : new file written
"mailbox.h" : new file written
"objdef.c" : new file written
"objdef.h" : new file written
"sdoserv.c" : new file written
"sdoserv.h" : new file written
Generate files finished
Create device description finished "C:\tmp\New folder\SSC-Device.xml"

Create Slave files finished
```

Create Files Finished

New files created successfully .

Figure 59: Configurator Create Files

[*Cancel*]
Close dialog without creating new files

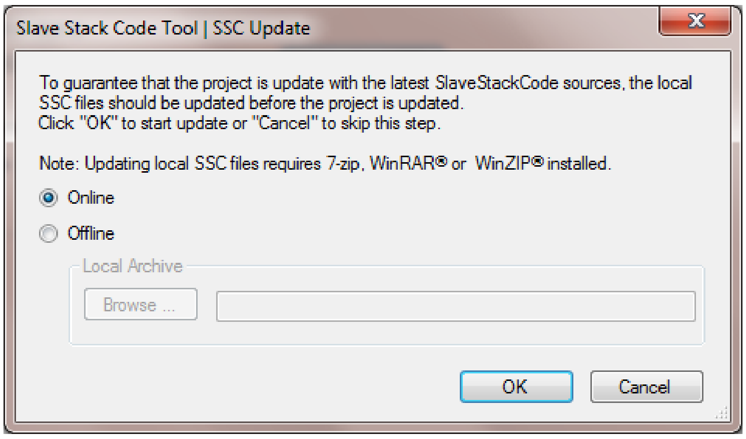
[*Close*]
Close dialog when new files were created.

[*Start*]
Create new slave files in the specified folder.

After new slave files are created a dialog appears to open the specified output folder or to return to the configurator.

12.4 Local SSC Update

Each new project is based on the local Slave Stack Code files. These files will be updated before a project update is started or when a new project is created (if this option is set).
The Slave Stack Code files are stored in application folder of the SSC Tool.
The update dialog is shown in Figure 60: Configurator Slave Stack Code Update.


Slave Stack Code Tool | SSC Update

To guarantee that the project is update with the latest SlaveStackCode sources, the local SSC files should be updated before the project is updated.
Click "OK" to start update or "Cancel" to skip this step.

Note: Updating local SSC files requires 7-zip, WinRAR® or WinZIP® installed.

[● Online]
Offline

Local Archive

Figure 60: Configurator Slave Stack Code Update

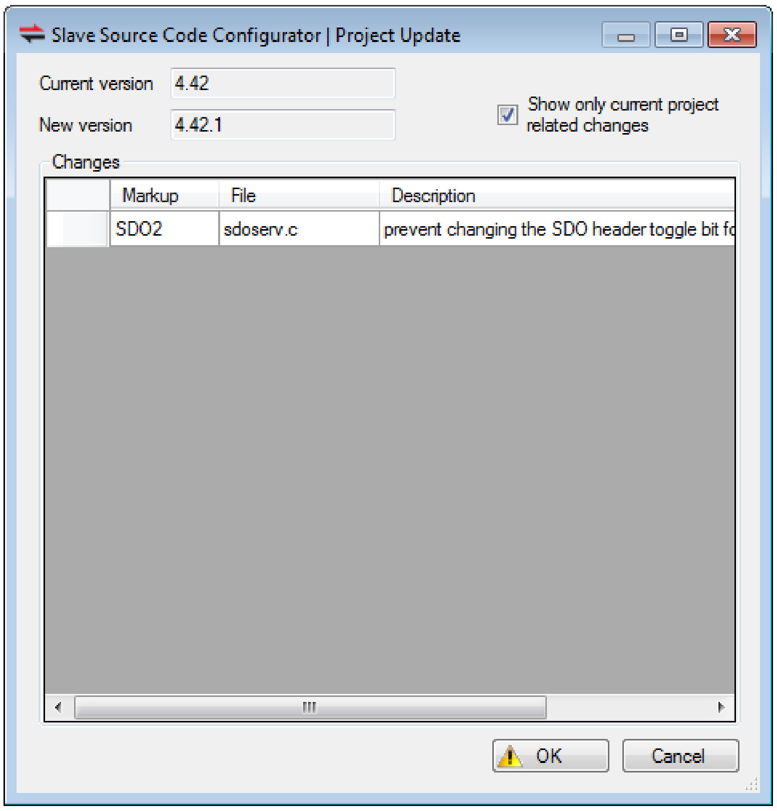
[*online*]
Load SSC files from the Beckhoff FTP server.

[*offline*]
Load SSC files from a local SSC zip archive.

Both options require an external archive tool (7-Zip, WinRAR® or WinZip®).

12.5 Project Update

The SSC Tool provides the possibility to update generic files within the current project to the latest version.
If new files are available the update dialog is show (Figure 61: Configurator Project Update Dialog).



Current version: 4.42
New version: 4.42.1
[✓] Show only current project related changes

	Markup	File	Description
	SDO2	sdoserv.c	prevent changing the SDO header toggle bit fo

Figure 61: Configurator Project Update Dialog

[*Current version*]
Slave Stack Code version of the current project

[*New version*]
Latest Slave Stack Code version available

[*Show only current project related changes*]
If checked only changes are shown which are related to the current project settings. Otherwise all changes are displayed.
NOTE: If checked only the latest changes are shown. Related changes which are older than one version are not displayed.

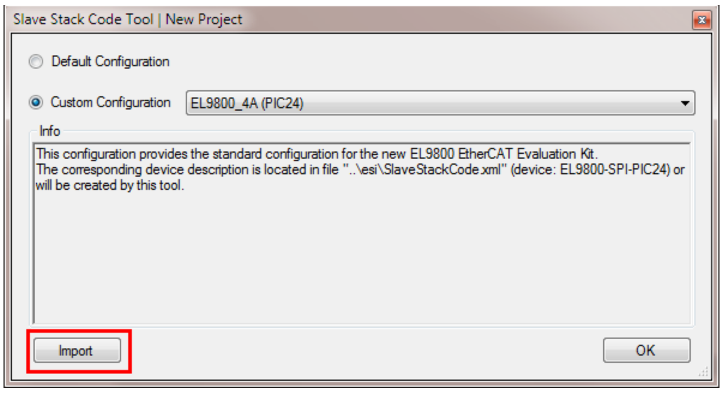
[*OK*]
Update current project. If an exclamation mark is show important information need to be acknowledged before the project is updated.

[*Cancel*]
Cancel project update

12.6 Import Configurations

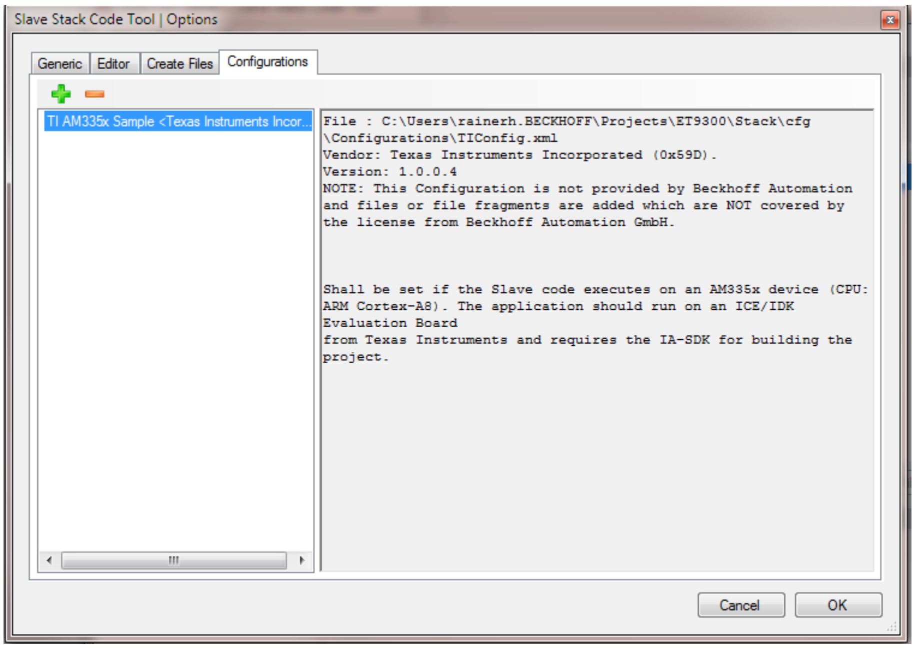
A configuration offers the possibility to manipulate SSC settings, to reference source files and add new elements ESI. By default a series of application-related configurations are available, but it is also possible to import new e.g. a configuration for the Texas Instruments AM335x.

Importing a Configuration can either be done via the new project dialog (Figure 62: New Project | Import Configuration) or the options menu (Figure 63: Options | Import Configuration).



This configuration provides the standard configuration for the new EL9800 EtherCAT Evaluation Kit.
The corresponding device description is located in file "..\esi\SlaveStackCode.xml" (device: EL9800-SPI-PIC24) or will be created by this tool.

Figure 62: New Project | Import Configuration


Slave Stack Code Tool | Options
Generic
Editor
Create Files
Configurations
TI AM335x Sample <Texas Instruments Incor...
Cancel
OK

```
File : C:\Users\rainerh.BECKHOFF\Projects\ET9300\Stack\cfg
\Configurations\TIConfig.xml
Vendor: Texas Instruments Incorporated (0x59D).
Version: 1.0.0.4
NOTE: This Configuration is not provided by Beckhoff Automation
and files or file fragments are added which are NOT covered by
the license from Beckhoff Automation GmbH.


Shall be set if the Slave code executes on an AM335x device (CPU:
ARM Cortex-A8). The application should run on an ICE/IDK
Evaluation Board
from Texas Instruments and requires the IA-SDK for building the
project.
```

Figure 63: Options | Import Configuration

NOTE: a Configuration may reference files which are not covered by the Beckhoff Automation GmbH license agreement. Contact the configuration vendor for further information.

13 OD Tool

The SSC OD Tool converts an application definition file to slave application files for the Beckhoff Slave Stack Code (Figure 64).

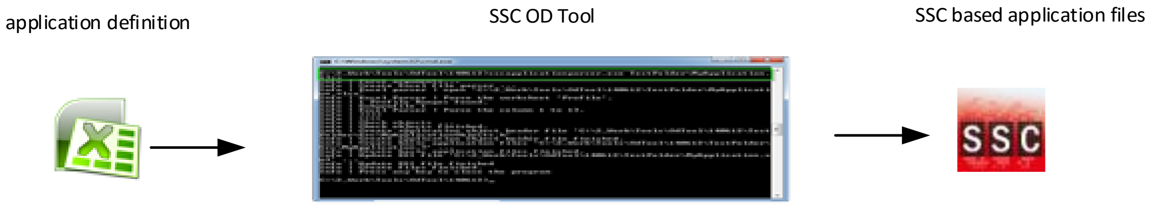


Figure 64: SSC OD Tool workflow

The supported definition file formats are:
- *xls ; *xlm ; *xlsx ; *xlsm
- *.xml
- *.eds

The tool can be either used as a console application (chapter 13.1) or by the Integration in the SSC Tool (chapter 13.2).

13.1 Console application

The console application (*SSC OD Tool.exe*) is located in the installation folder of the SSC Tool (e.g. “c:\Program Files (x86)\Beckhoff\EtherCAT Slave Stack Code Tool\SSC OD Tool.exe”.

Command line:

SSC OD Tool.exe *application_defintion_file*

Options:

/esi *existing_esi_file_to_update*

/src *folder_to_save_the_source_code*

NOTE:

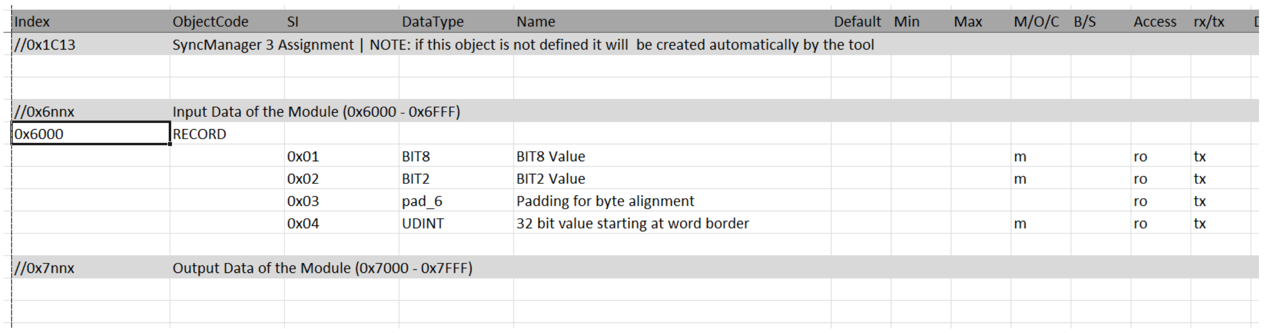
In case that an ESI file is located next to the application_defintion_file with the same name this ESI file will be update, the “/esi” option does not need to be set.

In case that that a “src” folder is located next to the application_defintion_file the source files will be generated in that folder, the “/src” option does not need to be set.

13.2 SSC Tool Integration

If an application definition file already exists it can be imported with the menu “Tool->Application->Import”.
If no application definition file exists a new *xlsx definition file is created by click “Tool->Application->Create new”. After the *xlsx editor is closed the application will be included to the slave project.

This chapter is handling the *.xlsx based application definition. An Example for an application definition is shown in Figure 65.



Index	ObjectCode	SI	DataType	Name	Default	Min	Max	M/O/C	B/S	Access	rx/tx
//0x1C13	SyncManager 3 Assignment | NOTE: if this object is not defined it will be created automatically by the tool										
//0x6nnx	Input Data of the Module (0x6000 - 0x6FFF)										
0x6000	RECORD										
		0x01	BIT8	BIT8 Value				m		ro	tx
		0x02	BIT2	BIT2 Value				m		ro	tx
		0x03	pad_6	Padding for byte alignment						ro	tx
		0x04	UDINT	32 bit value starting at word border				m		ro	tx
//0x7nnx	Output Data of the Module (0x7000 - 0x7FFF)										

Figure 65: Excel application definition example

The slave application data is organized in objects (see chapter 7). Only objects in the manufacturer specific range 0x2000 – 0x5FFF and the profile specific range 0x6000 – 0x9FFF shall be defined. The communication specific objects are generated automatically or they are configured via the SSC Tool.

13.3 PDO mapping and SM assign objects

The PDO mapping and SyncManager assign objects are generated automatically according the Modular Device Profile (MDP), as defined in ETG.5001-1 (Since ETG.5003 Semiconductor Device Profile uses the MDP structure, the tool also generated the objects for such object dictionaries). Mapping and Assign object generation is described in Table 21.

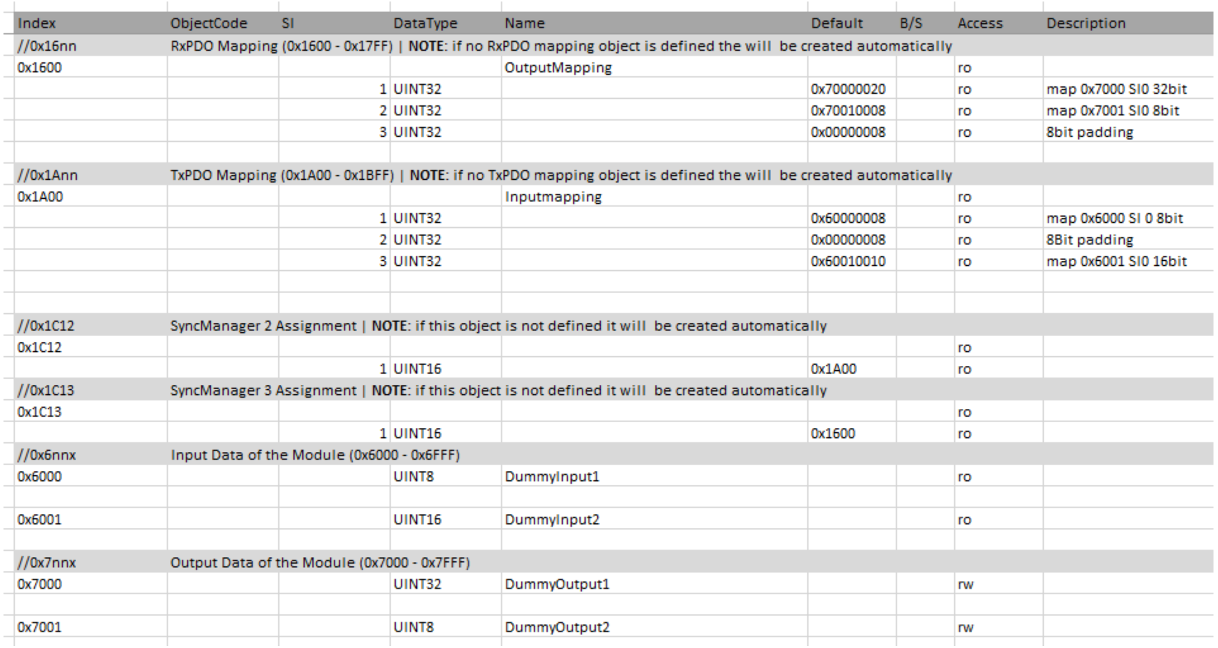
Table 21: PDO mapping and SM assign object generation

Index range	
0x2000 – 0x5FFF	Objects are added to the online and offline OD, but they are not added to the mapping objects
0x6FFF – 0x9FFF	Mapping and Assign rules apply, e.g. 0x6000 → 0x1A00 → 0x1C12:01 0x6010 → 0x1A01 → 0x1C12:02 0x6011 → 0x1A01 0x6020 → 0x1A02 … 0x7000 → 0x1600 → 0x1C13:01 0x7010 → 0x1601 → 0x1C13:02 0x7020 → 0x1602 → 0x1C13:03 ….

For profiles like CiA402 input objects and output objects are all mapped into one single input and output PDO.

13.3.1 Manual PDO mapping and SM assign description

In case that a manual PDO mapping and/or SM assignment is needed (e.g. in case of an expected padding within the process data) these object can be defined as shown in Figure 66.

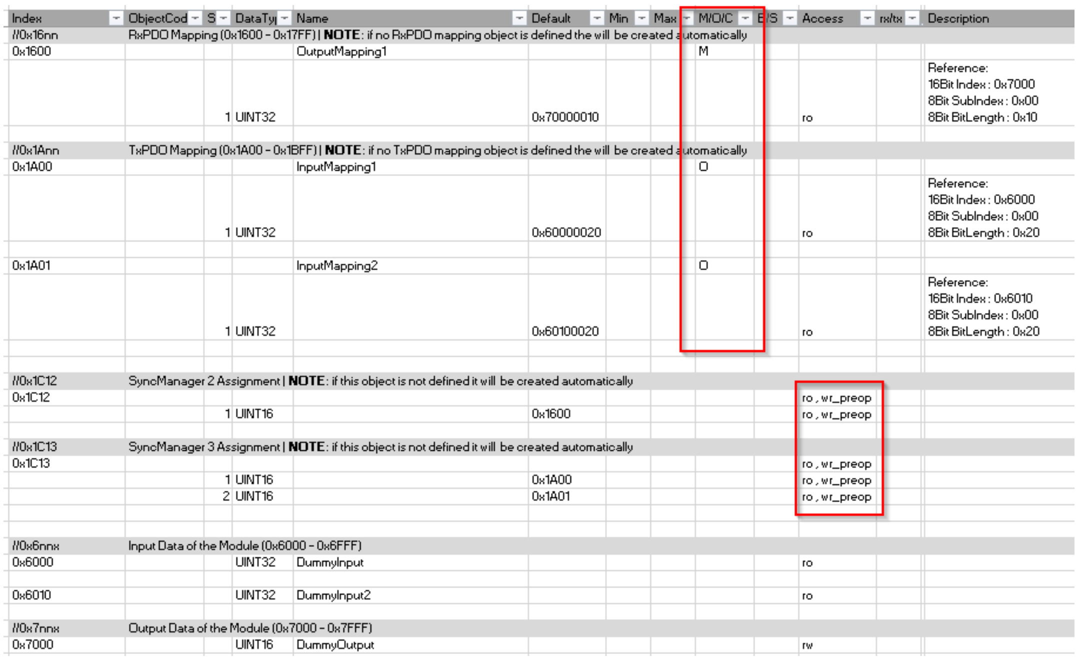


Index	ObjectCode	SI	DataType	Name	Default	B/S	Access	Description
//0x16nn	RxPDO Mapping (0x1600 - 0x17FF) | **NOTE**: if no RxPDO mapping object is defined the will be created automatically							
0x1600				OutputMapping			ro	
		1	UINT32		0x70000020		ro	map 0x7000 SI0 32bit
		2	UINT32		0x70010008		ro	map 0x7001 SI0 8bit
		3	UINT32		0x00000008		ro	8bit padding
//0x1Ann	TxPDO Mapping (0x1A00 - 0x1BFF) | **NOTE**: if no TxPDO mapping object is defined the will be created automatically							
0x1A00				Inputmapping			ro	
		1	UINT32		0x60000008		ro	map 0x6000 SI 0 8bit
		2	UINT32		0x00000008		ro	8Bit padding
		3	UINT32		0x60010010		ro	map 0x6001 SI0 16bit
//0x1C12	SyncManager 2 Assignment | **NOTE**: if this object is not defined it will be created automatically							
0x1C12							ro	
		1	UINT16		0x1A00		ro	
//0x1C13	SyncManager 3 Assignment | **NOTE**: if this object is not defined it will be created automatically							
0x1C13							ro	
		1	UINT16		0x1600		ro	
//0x6nnx	Input Data of the Module (0x6000 - 0x6FFF)							
0x6000			UINT8	DummyInput1			ro	
0x6001			UINT16	DummyInput2			ro	
//0x7nnx	Output Data of the Module (0x7000 - 0x7FFF)							
0x7000			UINT32	DummyOutput1			rw	
0x7001			UINT8	DummyOutput2			rw	

Figure 66: Maunal definition of PDO mapping and SM assign objects

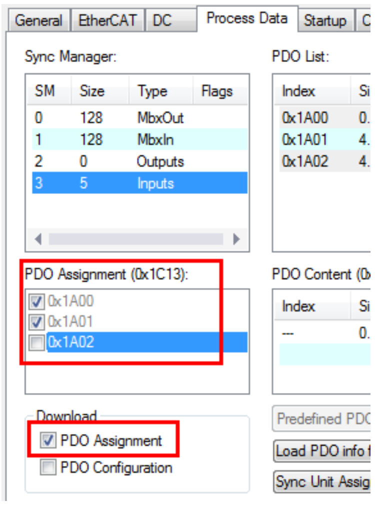
13.3.2 Flexible process data mapping/assignment

To support a flexible process data configuration the PDO Mapping and SM Assign object shall be defined manually. The PDO mapping and assign object shall be described as shown in Figure 67. Optional PDO mapping object shall be set to “O” (The column “M/O/C” is hidden by default) and the mandatory mapping are set to “M” or left empty.
The SM assign object shall be writeable in PreOP. Please note that all SM assign object shall be writeable even if only one is flexible.



Index	ObjectCod	S	DataTy	Name	Default	Min	Max	M/O/C	B/S	Access	rx/tx	Description
//0x16nn	RxPDO Mapping (0x1600 - 0x17FF) | **NOTE**: if no RxPDO mapping object is defined the will be created automatically											
0x1600				OutputMapping1				M				
		1	UINT32		0x70000010					ro		Reference: 16Bit Index : 0x7000 8Bit SubIndex : 0x00 8Bit BitLength : 0x10
//0x1Ann	TxPDO Mapping (0x1A00 - 0x1BFF) | **NOTE**: if no TxPDO mapping object is defined the will be created automatically											
0x1A00				InputMapping1				O				
		1	UINT32		0x60000020					ro		Reference: 16Bit Index : 0x6000 8Bit SubIndex : 0x00 8Bit BitLength : 0x20
0x1A01				InputMapping2				O				
		1	UINT32		0x60100020					ro		Reference: 16Bit Index : 0x6010 8Bit SubIndex : 0x00 8Bit BitLength : 0x20
//0x1C12	SyncManager 2 Assignment | **NOTE**: if this object is not defined it will be created automatically											
0x1C12										ro , wr_preop		
		1	UINT16		0x1600					ro , wr_preop		
//0x1C13	SyncManager 3 Assignment | **NOTE**: if this object is not defined it will be created automatically											
0x1C13										ro , wr_preop		
		1	UINT16		0x1A00					ro , wr_preop		
		2	UINT16		0x1A01					ro , wr_preop		
//0x6nnx	Input Data of the Module (0x6000 - 0x6FFF)											
0x6000			UINT32	DummyInput						ro		
0x6010			UINT32	DummyInput2						ro		
//0x7nnx	Output Data of the Module (0x7000 - 0x7FFF)											
0x7000			UINT16	DummyOutput						rw		

Figure 67: Description of a flexible PDO assignment



SM	Size	Type	Flags
0	128	MbxOut	
1	128	MbxIn	
2	0	Outputs	
3	5	Inputs	

Index	Si
0x1A00	0.
0x1A01	4.
0x1A02	4.

PDO Assignment (0x1C13):
- [x] 0x1A00
- [x] 0x1A01
- [ ] 0x1A02

Index	Si
---	0.

Download
- [x] PDO Assignment
- [ ] PDO Configuration

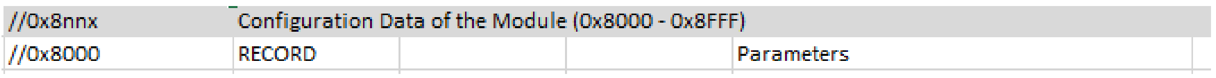
Figure 68: TwinCAT slave config PDO assignment

13.4 Syntax

The following chapter describes the syntax for the application definition file.

13.4.1 Comment

Single lines can be used as a comment line (ignored) by setting a leading “//” (Figure 69).



//0x8nnx	Configuration Data of the Module (0x8000 - 0x8FFF)				
//0x8000	RECORD			Parameters	

Figure 69: Application file comment

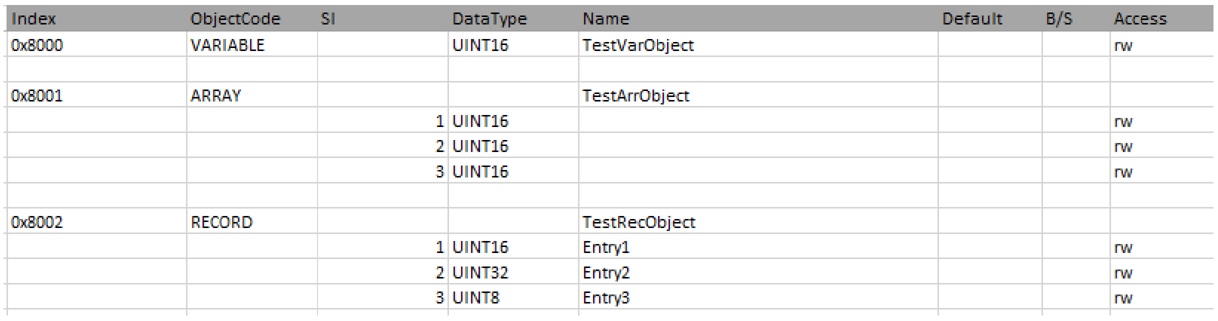
13.4.2 Object Index

The object index shall be of the format “0xZZZZ” (Z is a hexadecimal value) otherwise the complete line is skipped.

The following objects are fixed included in the SSC and shall not be defined in the file :
0x1000, 0x1001, 0x1008, 0x1009, 0x100A, 0x1010, 0x1011, 0x1018, 0x10F0, 0x10F1, 0x10F3, 0x10F8,0x1C00, 0x1C32, 0x1C33.

13.4.3 ObjectCode

Valid object codes are “VARIABLE”, “ARRAY” or “RECORD”. The code VARIABLE identifies an object a single entry, and ARRAY has multiple entries with the same base data type and a RECORD contains multiple entries with different base data types. Examples for different ObjectCodes are shown in Figure 70.
If this value is not set the object code will automatically set (based on the defined entries).



Index	ObjectCode	SI	DataType	Name	Default	B/S	Access
0x8000	VARIABLE		UINT16	TestVarObject			rw
0x8001	ARRAY			TestArrObject			
		1	UINT16				rw
		2	UINT16				rw
		3	UINT16				rw
0x8002	RECORD			TestRecObject			
		1	UINT16	Entry1			rw
		2	UINT32	Entry2			rw
		3	UINT8	Entry3			rw

Figure 70: ObjectCode Examples

In the generated ESI file and source code objects with the code ARRAY or RECORD will have an additional “Subindex0” entry which reflects the number of entries.

The generated source code variables based on the table in Figure 70 is as follows.

Object 0x8000:

```
PROTO UINT16 TestVarObject0x8000;
```

Object 0x8001:

```
typedef struct OBJ_STRUCT_PACKED_START {
      UINT16 u16SubIndex0;  /**< \brief Subindex 0 */
      UINT16 aEntries[3];  /**< \brief Subindex 1 - 3 */
} OBJ_STRUCT_PACKED_END
TOBJ8001;

/**
* \brief Object variable
*/
PROTO TOBJ8001 TestArrObject0x8001
#if defined(_APPL_EXAMPLE_) && (_APPL_EXAMPLE_ == 1)
={3,{0,0,0}}
#endif
;
```

Object 0x8002:

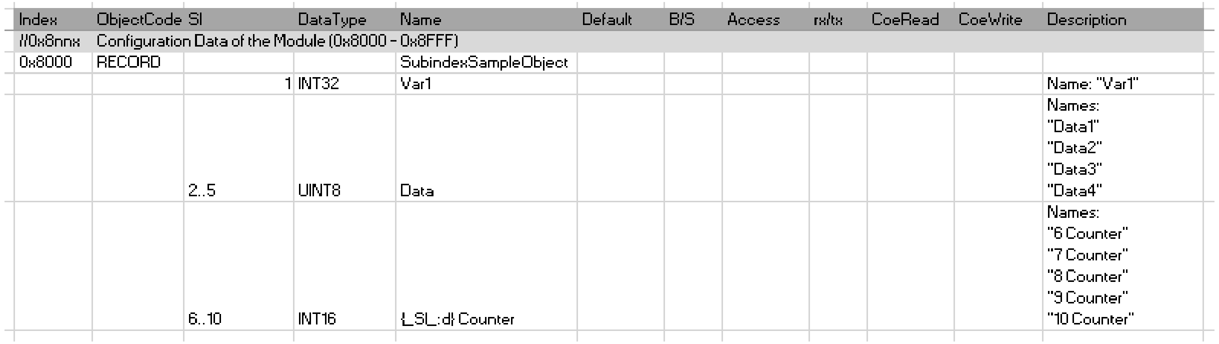
```
typedef struct OBJ_STRUCT_PACKED_START {
      UINT16 u16SubIndex0;
      UINT16 Entry1; /* Subindex1 - Entry1 */
      UINT32 Entry2; /* Subindex2 - Entry2 */
      UINT8 Entry3; /* Subindex3 - Entry3 */
} OBJ_STRUCT_PACKED_END
TOBJ8002;

/**
```

```
* \brief Object variable
*/
PROTO TOBJ8002 TestRecObject0x8002
#if defined(_APPL_EXAMPLE_) && (_APPL_EXAMPLE_ == 1)
={3,0,0,0}
#endif
;
```

13.4.4 SI (Subindex)

The Subindex can be either a decimal or hexadecimal value from 1 to 255. In case of an entry range the syntax “n..m” shall be used (e.g. 1..15). If the object code is record the entries may have defined names the placeholder “{_SI_:d}” can be used in the entry name, this placeholder will be replaced by the subindex (in the specified format). How to use the Subindex formats is shown in Figure 71.



Index	ObjectCode	SI	DataType	Name	Default	B/S	Access	rx/tx	CoeRead	CoeWrite	Description
//0x8nnx	Configuration Data of the Module (0x8000 - 0x8FFF)										
0x8000	RECORD			SubindexSampleObject							
		1	INT32	Var1							Name: "Var1"
		2..5	UINT8	Data							Names: "Data1" "Data2" "Data3" "Data4"
		6..10	INT16	{_SI_:d} Counter							Names: "6 Counter" "7 Counter" "8 Counter" "9 Counter" "10 Counter"

Figure 71: SubIndex definition examples

13.4.5 DataType

The following data types are supported. To set the entry data type the syntax in column “Base Data Type” or SSC Syntax shall be used.
When specifying the object structure the object design rules shall be taken into account (chapter 7.1).

To specify gaps a padding entry shall be added. Notation ”pad_x” where x defines the bit size from 1 to 15.

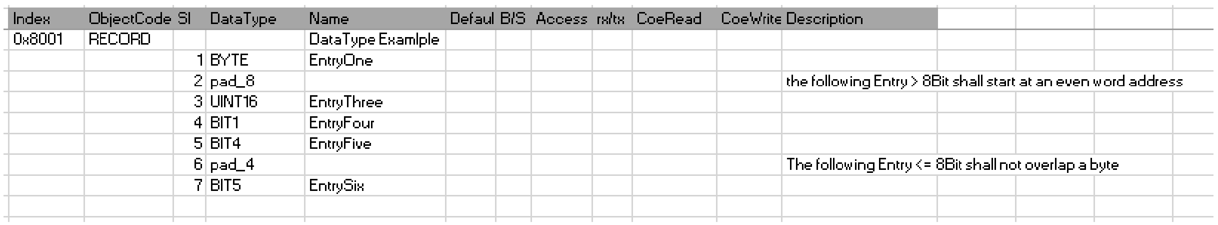
Table 22: Base Data Types describes the supported data types. See ETG.1020 for reference.

Table 22: Base Data Types

Index	Name	Base Data Type	Bit Size
0x0001	BOOLEAN	BOOL BIT	1
0x001E	BYTE	BYTE	8
0x001F	WORD	WORD	16
0x0020	DWORD	DWORD	32
0x0030	BIT1	BIT1	1
0x0031	BIT2	BIT2	2
0x0032	BIT3	BIT3	3
0x0033	BIT4	BIT4	4
0x0034	BIT5	BIT5	5
0x0035	BIT6	BIT6	6
0x0036	BIT7	BIT7	7

Index	Name	Base Data Type	Bit Size
0x0037	BIT8	BIT8	8
0x002D	BITARR8	BITARR8	8
0x002E	BITARR16	BITARR16	16
0x002F	BITARR32	BITARR32	32
0x0002	INTEGER8	SINT	8
0x0003	INTEGER16	INT	16
0x0004	INTEGER32	DINT	32
0x0015	INTEGER46	LINT	64
0x0005	UNSIGNED8	USINT	8
0x0006	UNSIGNED16	UINT	16
0x0007	UNSIGNED32	UDINT	32
0x00	UNSIGNED64	ULINT	64
0x0008	REAL32	REAL	32
0x0011	REAL64	LREAL	64
0x0009	VISIBLE_STRING	STRING(n)	8*n
0x000A	OCTET_STRING	ARRAY [0..n] OF BYTE	8*(n+1)
0x000B	UNICODE_STRING	ARRAY [0..n] OF UINT	16*(n+1)
0x0260	ARRAY_OF_INT	ARRAY [0..n] OF INT	16*(n+1)
0x0261	ARRAY_OF_SINT	ARRAY [0..n] OF SINT	8*(n+1)
0x0262	ARRAY_OF_DINT	ARRAY [0..n] OF DINT	32*(n+1)
0x0263	ARRAY_OF_UDINT	ARRAY [0..n] OF UDINT	32*(n+1)

An example is shown in Figure 72.

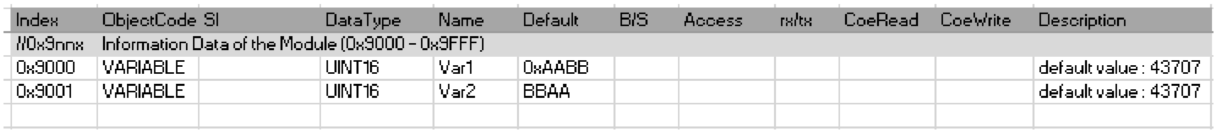


Index	ObjectCode	SI	DataType	Name	Defaul	B/S	Access	rx/tx	CoeRead	CoeWrite	Description
0x8001	RECORD			DataType Examlple							
		1	BYTE	EntryOne							
		2	pad_8								the following Entry > 8Bit shall start at an even word address
		3	UINT16	EntryThree							
		4	BIT1	EntryFour							
		5	BIT4	EntryFive							
		6	pad_4								The following Entry <= 8Bit shall not overlap a byte
		7	BIT5	EntrySix							

Figure 72: Entry DataType example

13.4.6 Default/Min/Max

The columns “Min”/”Max” are not evaluated by the SSC and can empty. The column “Default” defines the default data of an entry. These shall be set as a hex value in little endian or big endian (with a leading “0x”). Always the bytes shall be defined (as shown in Figure 73: Default data example).



Index	ObjectCode	SI	DataType	Name	Default	B/S	Access	rx/tx	CoeRead	CoeWrite	Description
//0x9nnx	Information Data of the Module (0x9000 - 0x9FFF)										
0x9000	VARIABLE		UINT16	Var1	0xAABB						default value : 43707
0x9001	VARIABLE		UINT16	Var2	BBAA						default value : 43707

Figure 73: Default data example

13.4.7 M/O/C, B/S and rx/tx

The column "**M/O/C**" defines if an entry is mandatory optional or conditional. This value is only set in the ESI file and has no influence to the slave application.
The column "**B/S**" specifies if an entry is a backup or setting object.
The column "**rx/tx**" specifies if an entry is rx or tx PDO map able.

13.4.8 Access

Defines the access rights via CoE. The access (read, write, readwrite) can be identical in PreOp, SafeOp, Op. Or they can be different in some states. Example: A configuration value may be readable and writeable in PreOp, but must not be changed any more in Op.
the allowed values are listed in Table 23: Entry access rights.

Table 23: Entry access rights

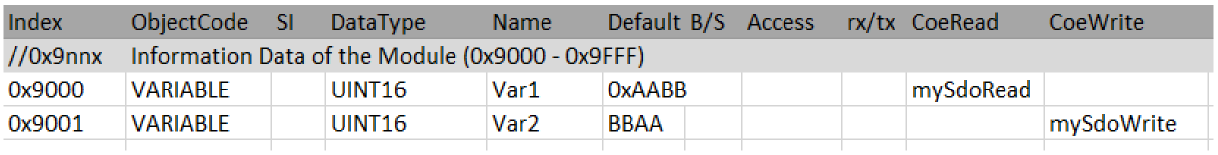
Syntax	Description
RO	Read-only in all states
WO	Write-only in all states
RW	Readable and writable in all states
rd_preop	Readonly in Preop
rd_preop_safeop	Read-only in PreOP and SafeOP
rd _safeop	Read-only in SafeOP
rd_ safeop_op	Read-only in SafeOP and OP
rd _op	Read-only in OP
wr_preop	Write only in PreOP
wr _preop_safeop	Write only in PreOP and SafeOP
wr _safeop	Write only in SafeOP
wr _Safeop_op	Write only in SafeOP and OP
wr _op	Write only in OP

The state-dependent access rights shall be separated by a comma (,).

e.g. an entry shall readonly in SafeOP and OP and writeable in PreOP to access is "ro , wr_preop".

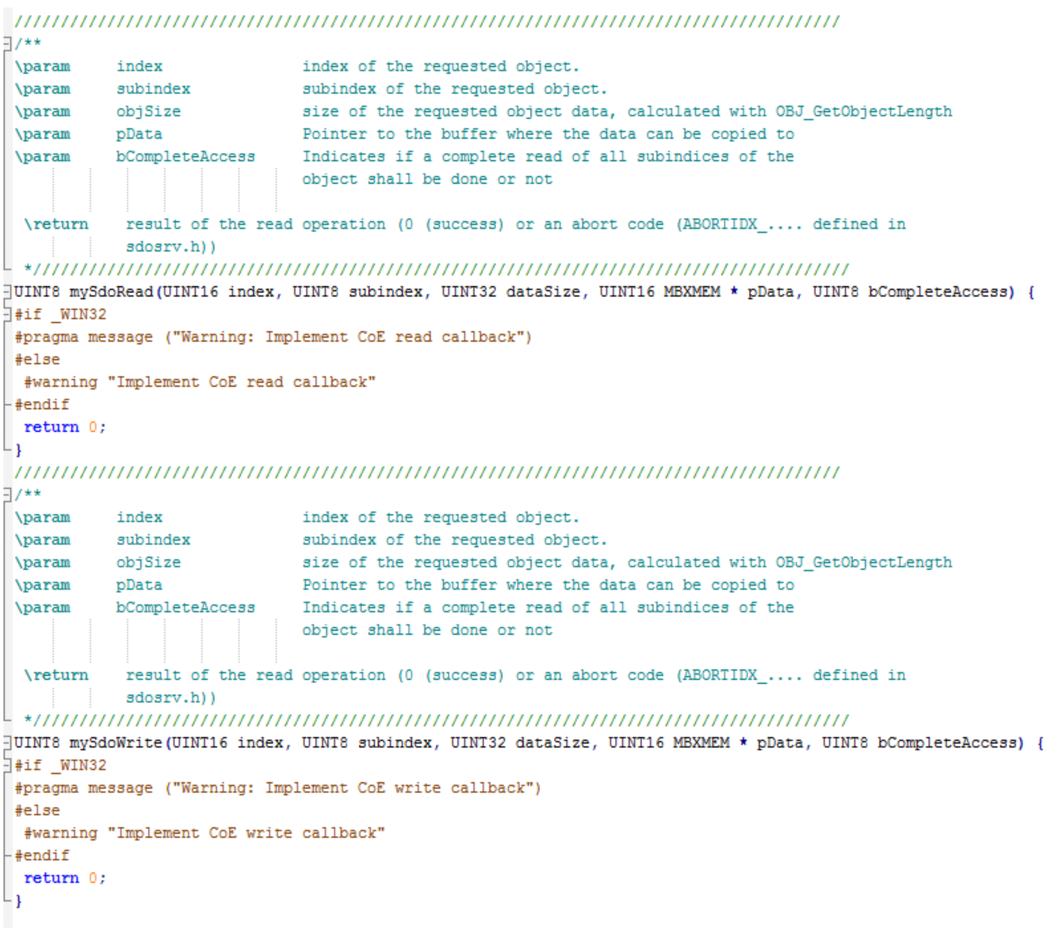
13.4.9 CoeRead/CoeWrite

In case that CoE read and write requests shall be handled by the application a function name can be added to these columns (Figure 74: CoeRead/CoeWrite example). The parser will create the corresponding declaration (in the xxxObjects.h) and (in case that the application c file does not exist) the dummy function body in the application c file (Figure 75).



Index	ObjectCode	SI	DataType	Name	Default	B/S	Access	rx/tx	CoeRead	CoeWrite
//0x9nnx	Information Data of the Module (0x9000 - 0x9FFF)									
0x9000	VARIABLE		UINT16	Var1	0xAABB				mySdoRead	
0x9001	VARIABLE		UINT16	Var2	BBAA					mySdoWrite

Figure 74: CoeRead/CoeWrite example



```
////////////////////////////////////////////////////////////////////////////////////////
/**
\param     index                index of the requested object.
\param     subindex             subindex of the requested object.
\param     objSize              size of the requested object data, calculated with OBJ_GetObjectLength
\param     pData                Pointer to the buffer where the data can be copied to
\param     bCompleteAccess      Indicates if a complete read of all subindices of the
                                object shall be done or not

 \return    result of the read operation (0 (success) or an abort code (ABORTIDX_.... defined in
            sdosrv.h))
 *////////////////////////////////////////////////////////////////////////////////////////
UINT8 mySdoRead(UINT16 index, UINT8 subindex, UINT32 dataSize, UINT16 MBXMEM * pData, UINT8 bCompleteAccess) {
#if _WIN32
#pragma message ("Warning: Implement CoE read callback")
#else
 #warning "Implement CoE read callback"
#endif
 return 0;
}
////////////////////////////////////////////////////////////////////////////////////////
/**
\param     index                index of the requested object.
\param     subindex             subindex of the requested object.
\param     objSize              size of the requested object data, calculated with OBJ_GetObjectLength
\param     pData                Pointer to the buffer where the data can be copied to
\param     bCompleteAccess      Indicates if a complete read of all subindices of the
                                object shall be done or not

 \return    result of the read operation (0 (success) or an abort code (ABORTIDX_.... defined in
            sdosrv.h))
 *////////////////////////////////////////////////////////////////////////////////////////
UINT8 mySdoWrite(UINT16 index, UINT8 subindex, UINT32 dataSize, UINT16 MBXMEM * pData, UINT8 bCompleteAccess) {
#if _WIN32
#pragma message ("Warning: Implement CoE write callback")
#else
 #warning "Implement CoE write callback"
#endif
 return 0;
}
```

Figure 75: CoeRead/CoeWrite example function body

13.5 ENUM

Enums shall be defined in the index range 0x800 to 0xFFF (see also ETG.1000-6).
The used name and data type shall be “DTXXXXENYY”. XXXX is the index of the enumeration and YY the used bit size.

Example

Table 24 shows an Enum definition example.

Table 24: Enum definition

//Index	ObjectCode	SI	DataType	M/O/C	Access	Default	Name
0x0800							DT0800EN03
		1				1	Signed
		2				2	Unsigned

Table 25 shows an example for an entry using the above defined Enum.

Table 25: Enum usage

//Index	ObjectCode	SI	DataType	M/O/C	Acces s	Default	Name
0x8nn0	RECORD						
		0x01	Pad_16				
		0x11	DT0800EN03	M	RO	2	Presentation

14 EEPROM Handling

To identify an EtherCAT slave and to provide parameter (e.g. process data, supported mailbox protocols) every EtherCAT slave has to have a SII (Slave Information Interface).
Usually this information is stored in an EEPROM which is connected via an I²C to the ESC. Depending on the used ESC (see ESC datasheet) it is also possible to emulate the EEPROM, which means the data is stored in the application memory and is handled by the slave application.

14.1 EEPROM Emulation

Since SSC version 5.01 EEPROM Emulation is supported and can be controlled by the defines listed in Table 26: EEPROM Emulation Defines.

Table 26: EEPROM Emulation Defines

Define	Description
ESC_EEPROM_EMULATION	If set to 1, the EEPROM emulation is enabled and EEPROM commands are handled by the SSC.
CREATE_EEPROM_CONTENT	Only available in the SSC Tool. If set to 1, then a header file including the EEPROM data according to the slave configuration will be created during the slave file generation process (see chapter 12.3 Create Files).
ESC_EEPROM_SIZE	Available EEPROM buffer size in Bytes.
EEPROM_READ_SIZE	Number of Bytes the ESC can handle on a single read access. See ESC datasheet for further details. ET1100/ET1200 : 8Byte
EEPROM_WRITE_SIZE	Number of Bytes the ESC can handle on a single write access. This value is always 2.

The EEPROM emulation can be either implemented by application callback functions or by a static EEPROM data array.

Callback functions : Read/Write and reload function are described in chapter 6.2.1.

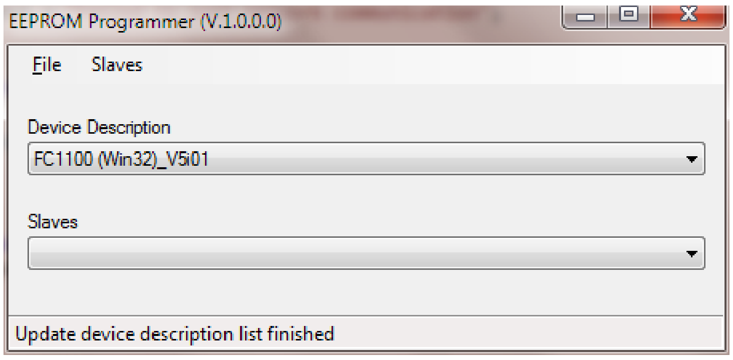
Static EEPROM data : The EEPROM content is stored in an static array, and accessed by the global pointer "pEEPROM" (defined in *ecatappl.h*.) and need to be initialized during startup. On an EEPROM reload command the function "HW_EepromReload" is called which shall update the Station Alias and Enhanced link detection in the EEPROM array (see SII Specification for the corresponding offsets).

In case that register 0x502 bit6 is set to 1 (8 Byte EEPROM access) the full EEPROM emulation is enabled and the reload commands are not required (reload commands are handled similar to EEPROM read).

Generating EEPROM content is required if the slave application has changed after the slave file generation with the SSC Tool or if the basic SSC is used for the slave development. Therefore an additional "EEPROM Programming" tool is provided (see chapter 14.2).

14.2 EEPROM Programming

Where a physical EEPROM is available or the EEPROM is emulated the EEPROM content needs to be generated. This can be done in multiple ways, e.g. with TwinCAT (see [3]) or by the EEPROM programming tool (Figure 76: EEPROM Programming Tool) which is described in this chapter.



Update device description list finished

Figure 76: EEPROM Programming Tool

14.2.1 EEPROM Programmer User Elements

File menu (Figure 77: EEPROM Programmer | File):

[Open]: Open an ESI file.

[Save as]: Save the EEPROM data in a binary or a header file.

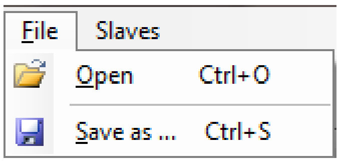


Figure 77: EEPROM Programmer | File

Slaves menu (Figure 78: EEPROM Programmer | Slaves):

[Scan]: Scans for connected EtherCAT slaves on the available network cards.

[Program Selected]: Program the EEPROM of the slave selected in the slave list.

[Program All]: Program the EEPROM of all slaves found.

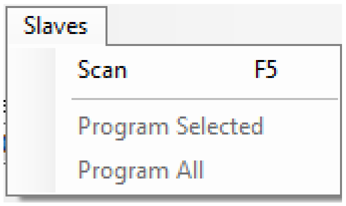


Figure 78: EEPROM Programmer | Slaves

List elements (Figure 79: EEPROM Programmer | List Elements):

[Device Description]: List of all device descriptions defined in the ESI file opened.

[Slaves]: List of all slaves connected.

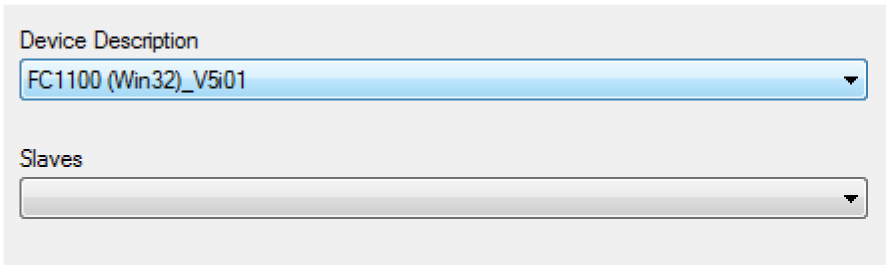


Figure 79: EEPROM Programmer | List Elements

14.2.2 Example Programming EEPROM

1.) Open the EEPROM Programmer

   a. SSC Tool : “Tool” -> “EEPROM Programmer”

   b. Start Menu -> Programs -> EtherCAT Slave Stack Code Tool -> EEPROM Programmer

2.) In case that the programmer is not started from the SSC Tool an ESI has to be selected (“File”-> “Open”)

3.) Scan for connected EtherCAT slaves (“F5” or “Slaves” -> “Scan”)

4.) Program

   a. Program only a single EEPROM (of the selected slave), “Slaves”-> “”Program Selected”

   b. Program all EEPROMs, “Slaves” -> “Program All”

15 Bootloader

The SSC is prepared to be used as the base code for a Bootloader implementation. The basic bootloader features are the Bootstate and firmware download. Both features are already fully provided by the SSC and can be enabled by the following defines:

- BOOTSTRAPMODE_SUPPORTED
- FOE_SUPPORTED

The following functions are intent to be used in the firmware download process:

BL_Start(): Called in the state transition from INIT to BOOT

BL_StartDownload(): Called on a write request in case that the file name starts with "ECATFW__" (the file name is specified in aFirmwareDownloadHeader (foeappl.c)

BL_Data(): Called on every data fragment

The firmware update itself (e.g. writing the flash and reset the Controller) can either be done during the FoE file download or on the transition from BOOT to INIT. Which mechanism is implement is up to the slave vendor.

For further information about the recommend slave behavior during a state transition see the ETG.5003.2.

16 Process Data

The process data is handled by three functions:

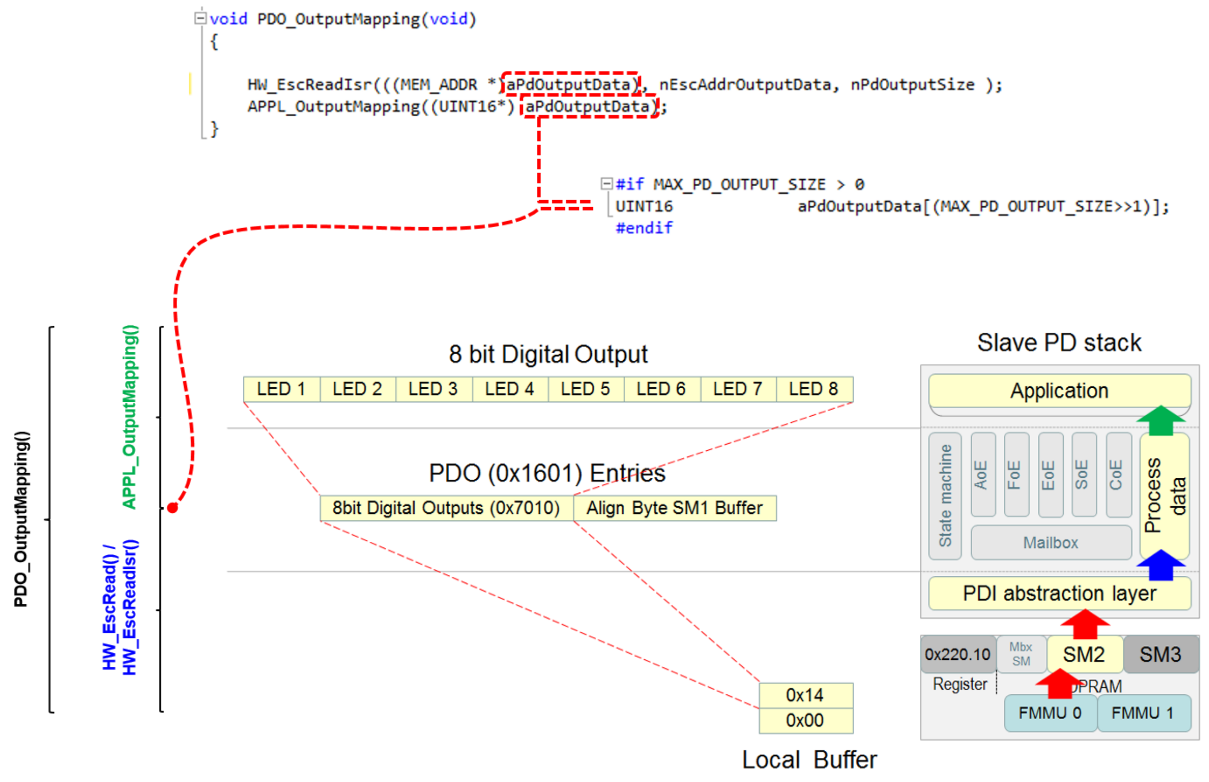
PDO_OutputMapping()

ECAT_Application()

PDO_InputMapping()

The function are called based on the configured sync mode (see 9 Synchronization).

Example for process data output mapping (Figure 80):

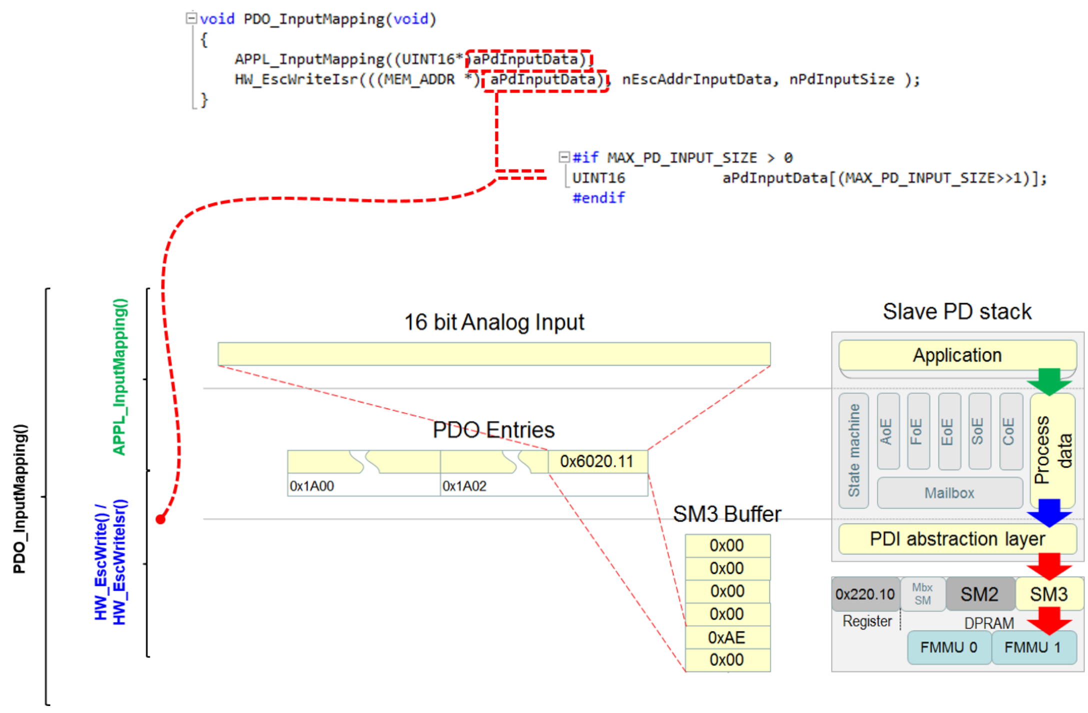


```
void PDO_OutputMapping(void)
{
    HW_EscReadIsr(((MEM_ADDR *)aPdOutputData), nEscAddrOutputData, nPdOutputSize );
    APPL_OutputMapping((UINT16*) aPdOutputData);
}
```

```
#if MAX_PD_OUTPUT_SIZE > 0
UINT16              aPdOutputData[(MAX_PD_OUTPUT_SIZE>>1)];
#endif
```

Figure 80: Output mapping example

An example for input mapping is shown in Figure 81



```
void PDO_InputMapping(void)
{
    APPL_InputMapping((UINT16*)aPdInputData);
    HW_EscWriteIsr(((MEM_ADDR *) aPdInputData), nEscAddrInputData, nPdInputSize );
}
```

```
#if MAX_PD_INPUT_SIZE > 0
UINT16          aPdInputData[(MAX_PD_INPUT_SIZE>>1)];
#endif
```

Figure 81: Input mapping example

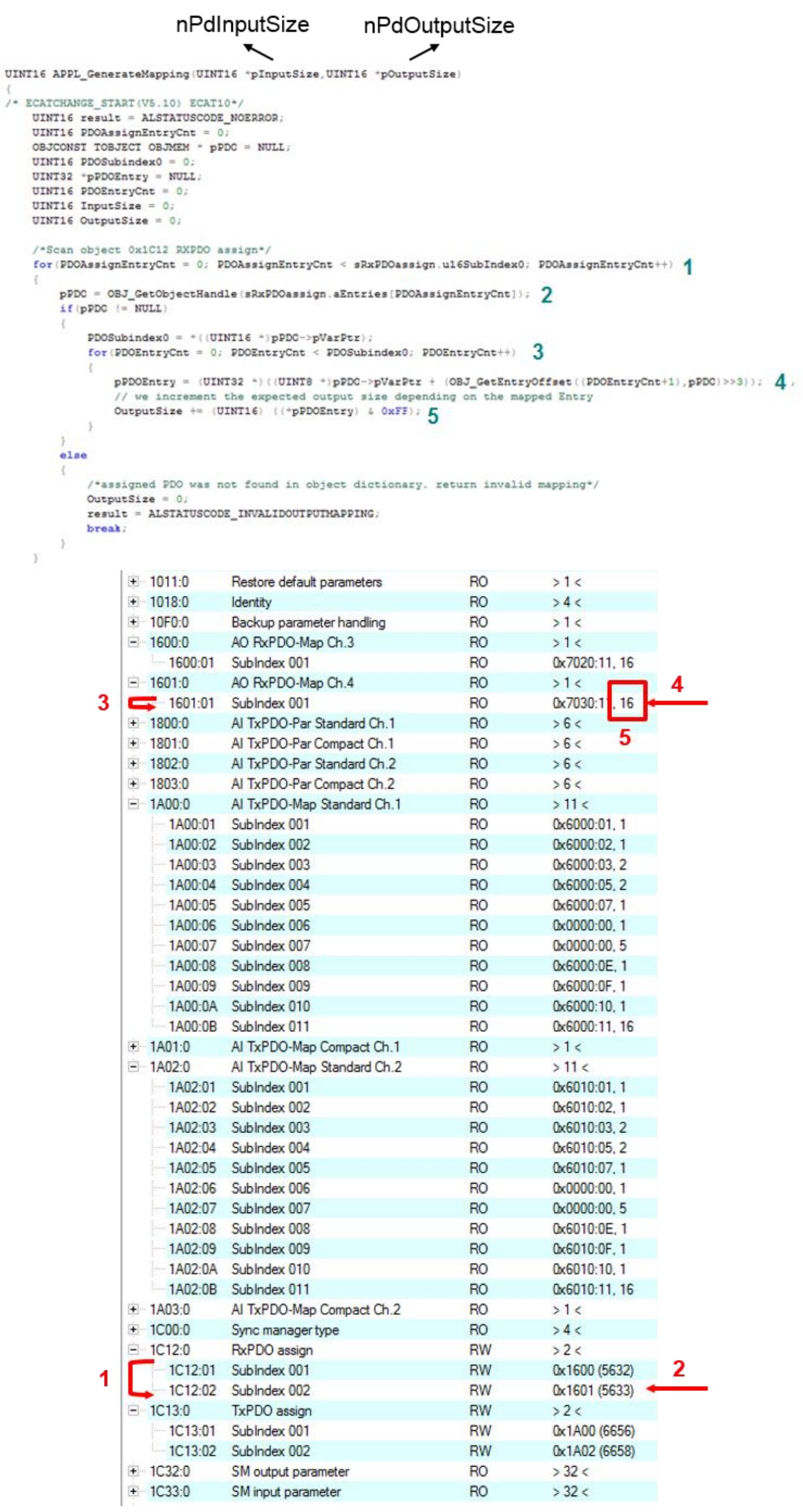
16.1 Process data size

Function **APPL_GenerateMapping()** calculates the size of Output and Input Process Data, which can vary according to the PDO mapping. It is called by AL_ControlInd() during the PREOP_2_SAFEOP transition, and in case of error it returns AL Status Codes 0x24 “Invalid Input Mapping” and 0x25 “Invalid Output Mapping” (an error is returned if the function does not manage to get a pointer to one of the 0x16yz and 0x1Ayz expected by the 0x1C12 and 0x1C13, respectively).

This function has to be implemented by users, yet examples reported in ___appl.c files of SSC represent a general algorithm.

The following example shows the calculation for RxPDOs (Figure 82):

1. Object 0x1C12 “RxPDO Assign” is parsed
2. Each entry of 0x1C12 corresponds to a “RxPDO Mapping” Object 0x16yz
3. The corresponding Object 0x16yz “RxPDO Mapping” is parsed
4. Each entry of 0x16yz corresponds to a mapped output entry
5. The size of all mapped output entries are added in order to obtain nPdOutputSize



```
UINT16 APPL_GenerateMapping(UINT16 *pInputSize,UINT16 *pOutputSize)
{
/* ECATCHANGE_START(V5.10) ECAT10*/
    UINT16 result = ALSTATUSCODE_NOERROR;
    UINT16 PDOAssignEntryCnt = 0;
    OBJCONST TOBJECT OBJMEM * pPDO = NULL;
    UINT16 PDOSubindex0 = 0;
    UINT32 *pPDOEntry = NULL;
    UINT16 PDOEntryCnt = 0;
    UINT16 InputSize = 0;
    UINT16 OutputSize = 0;

    /*Scan object 0x1C12 RXPDO assign*/
    for(PDOAssignEntryCnt = 0; PDOAssignEntryCnt < sRxPDOassign.u16SubIndex0; PDOAssignEntryCnt++)  1
    {
        pPDO = OBJ_GetObjectHandle(sRxPDOassign.aEntries[PDOAssignEntryCnt]);  2
        if(pPDO != NULL)
        {
            PDOSubindex0 = *((UINT16 *)pPDO->pVarPtr);
            for(PDOEntryCnt = 0; PDOEntryCnt < PDOSubindex0; PDOEntryCnt++)  3
            {
                pPDOEntry = (UINT32 *)((UINT8 *)pPDO->pVarPtr + (OBJ_GetEntryOffset((PDOEntryCnt+1),pPDO)>>3));  4
                // we increment the expected output size depending on the mapped Entry
                OutputSize += (UINT16) ((*pPDOEntry) & 0xFF);  5
            }
        }
        else
        {
            /*assigned PDO was not found in object dictionary. return invalid mapping*/
            OutputSize = 0;
            result = ALSTATUSCODE_INVALIDOUTPUTMAPPING;
            break;
        }
    }
```

1011:0	Restore default parameters	RO	> 1 <
1018:0	Identity	RO	> 4 <
10F0:0	Backup parameter handling	RO	> 1 <
1600:0	AO RxPDO-Map Ch.3	RO	> 1 <
1600:01	SubIndex 001	RO	0x7020:11, 16
1601:0	AO RxPDO-Map Ch.4	RO	> 1 <
1601:01	SubIndex 001	RO	0x7030:11, 16
1800:0	AI TxPDO-Par Standard Ch.1	RO	> 6 <
1801:0	AI TxPDO-Par Compact Ch.1	RO	> 6 <
1802:0	AI TxPDO-Par Standard Ch.2	RO	> 6 <
1803:0	AI TxPDO-Par Compact Ch.2	RO	> 6 <
1A00:0	AI TxPDO-Map Standard Ch.1	RO	> 11 <
1A00:01	SubIndex 001	RO	0x6000:01, 1
1A00:02	SubIndex 002	RO	0x6000:02, 1
1A00:03	SubIndex 003	RO	0x6000:03, 2
1A00:04	SubIndex 004	RO	0x6000:05, 2
1A00:05	SubIndex 005	RO	0x6000:07, 1
1A00:06	SubIndex 006	RO	0x0000:00, 1
1A00:07	SubIndex 007	RO	0x0000:00, 5
1A00:08	SubIndex 008	RO	0x6000:0E, 1
1A00:09	SubIndex 009	RO	0x6000:0F, 1
1A00:0A	SubIndex 010	RO	0x6000:10, 1
1A00:0B	SubIndex 011	RO	0x6000:11, 16
1A01:0	AI TxPDO-Map Compact Ch.1	RO	> 1 <
1A02:0	AI TxPDO-Map Standard Ch.2	RO	> 11 <
1A02:01	SubIndex 001	RO	0x6010:01, 1
1A02:02	SubIndex 002	RO	0x6010:02, 1
1A02:03	SubIndex 003	RO	0x6010:03, 2
1A02:04	SubIndex 004	RO	0x6010:05, 2
1A02:05	SubIndex 005	RO	0x6010:07, 1
1A02:06	SubIndex 006	RO	0x0000:00, 1
1A02:07	SubIndex 007	RO	0x0000:00, 5
1A02:08	SubIndex 008	RO	0x6010:0E, 1
1A02:09	SubIndex 009	RO	0x6010:0F, 1
1A02:0A	SubIndex 010	RO	0x6010:10, 1
1A02:0B	SubIndex 011	RO	0x6010:11, 16
1A03:0	AI TxPDO-Map Compact Ch.2	RO	> 1 <
1C00:0	Sync manager type	RO	> 4 <
1C12:0	RxPDO assign	RW	> 2 <
1C12:01	SubIndex 001	RW	0x1600 (5632)
1C12:02	SubIndex 002	RW	0x1601 (5633)
1C13:0	TxPDO assign	RW	> 2 <
1C13:01	SubIndex 001	RW	0x1A00 (6656)
1C13:02	SubIndex 002	RW	0x1A02 (6658)
1C32:0	SM output parameter	RO	> 32 <
1C33:0	SM input parameter	RO	> 32 <

Figure 82: Calculate process data size example

16.2 Watchdog

Every EtherCAT slave with output process data has to support a process data watchdog. This watchdog can either be implement in a local timer in software or the ESC internal watchdog can be used (selected by the define “ESC_WD_SUPPORTED”) (Figure 83).

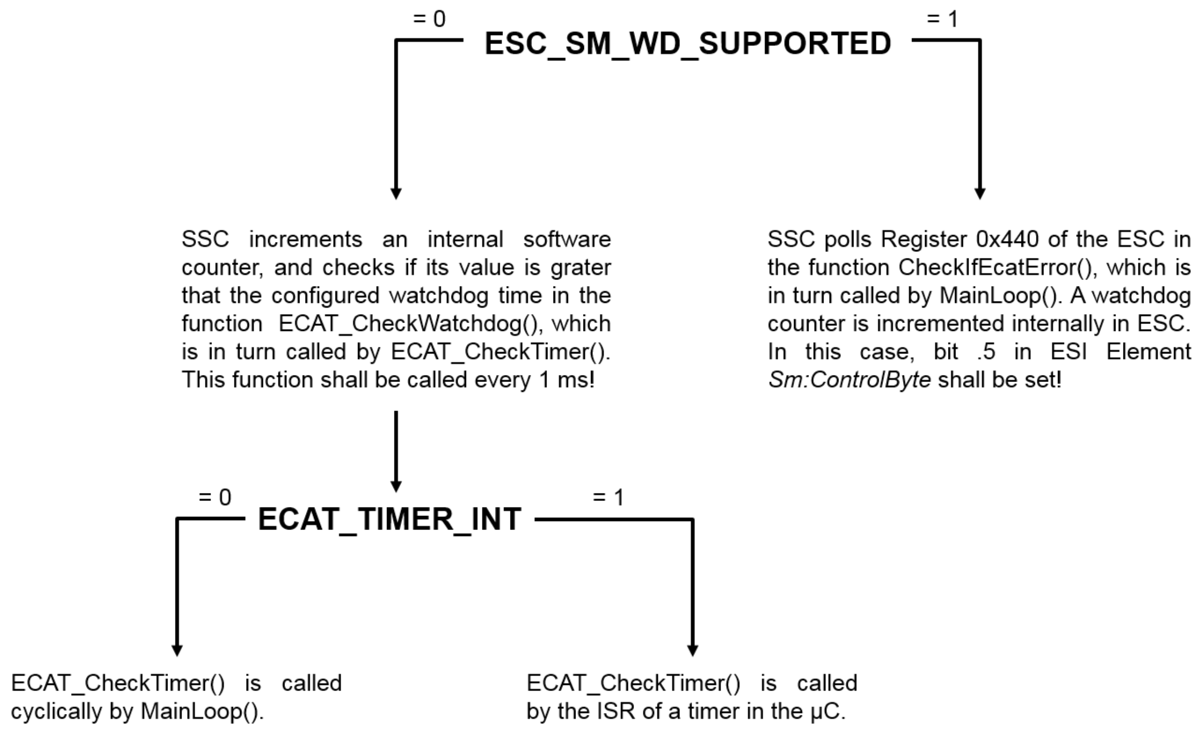
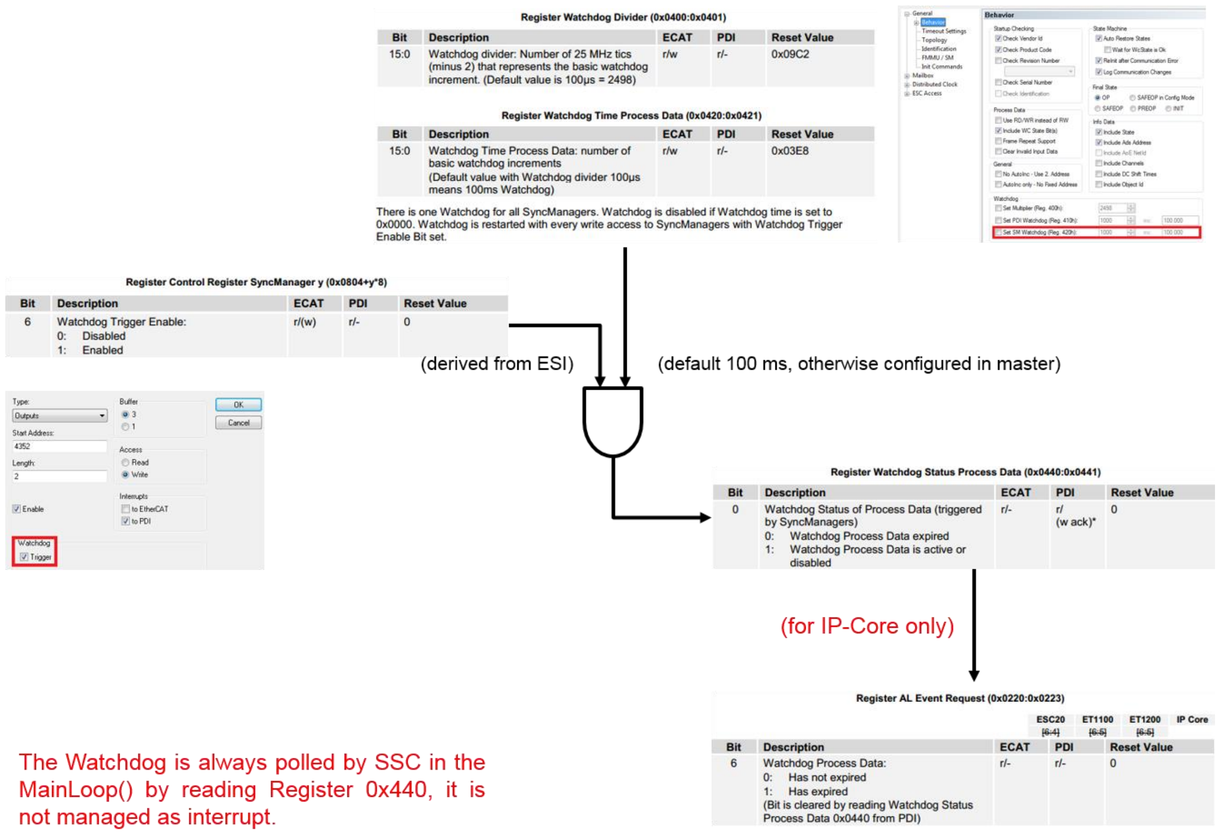

= 0
ESC_SM_WD_SUPPORTED
= 1
SSC increments an internal software counter, and checks if its value is grater that the configured watchdog time in the function ECAT_CheckWatchdog(), which is in turn called by ECAT_CheckTimer(). This function shall be called every 1 ms!
SSC polls Register 0x440 of the ESC in the function CheckIfEcatError(), which is in turn called by MainLoop(). A watchdog counter is incremented internally in ESC. In this case, bit .5 in ESI Element Sm:ControlByte shall be set!
= 0
ECAT_TIMER_INT
= 1
ECAT_CheckTimer() is called cyclically by MainLoop().
ECAT_CheckTimer() is called by the ISR of a timer in the µC.

Figure 83: Process data watchdog defines

Figure 84 shows the process data watchdog configuration in the ESC. In case that the local timer is used for the watchdog only the watchdog time will we read out from the ESC.



Register Watchdog Divider (0x0400:0x0401)

Bit	Description	ECAT	PDI	Reset Value
15:0	Watchdog divider: Number of 25 MHz tics (minus 2) that represents the basic watchdog increment. (Default value is 100µs = 2498)	r/w	r/-	0x09C2

Register Watchdog Time Process Data (0x0420:0x0421)

Bit	Description	ECAT	PDI	Reset Value
15:0	Watchdog Time Process Data: number of basic watchdog increments (Default value with Watchdog divider 100µs means 100ms Watchdog)	r/w	r/-	0x03E8

There is one Watchdog for all SyncManagers. Watchdog is disabled if Watchdog time is set to 0x0000. Watchdog is restarted with every write access to SyncManagers with Watchdog Trigger Enable Bit set.

General / Behavior / Timeout Settings / Topology / Identification / FMMU / SM / Init Commands / Mailbox / Distributed Clock / ESC Access

Behavior

Startup Checking: [✓] Check Vendor Id; [✓] Check Product Code; [ ] Check Revision Number; [ ] Check Serial Number; [ ] Check Identification

State Machine: [✓] Auto Restore States; [ ] Wait for WcState is Ok; [✓] ReInit after Communication Error; [✓] Log Communication Changes

Final State: [✓ OP] SAFEOP in Config Mode; SAFEOP; PREOP; INIT

Process Data: [ ] Use RD/WR instead of RW; [✓] Include WC State Bit(s); [ ] Frame Repeat Support; [ ] Clear Invalid Input Data

Info Data: [✓] Include State; [✓] Include Ads Address; [ ] Include AoE NetId; [ ] Include Channels; [ ] Include DC Shift Times; [ ] Include Object Id

General: [ ] No AutoInc - Use 2. Address; [ ] AutoInc only - No Fixed Address

Watchdog: [ ] Set Multiplier (Reg. 400h): 2498; [ ] Set PDI Watchdog (Reg. 410h): 1000 ms: 100.000; [ ] Set SM Watchdog (Reg. 420h): 1000 ms: 100.000

Register Control Register SyncManager y (0x0804+y*8)

Bit	Description	ECAT	PDI	Reset Value
6	Watchdog Trigger Enable: 0: Disabled 1: Enabled	r/(w)	r/-	0

Type: Outputs; Start Address: 4352; Length: 2; [✓] Enable; Buffer: [✓ 3] 1; Access: Read [✓ Write]; Interrupts: [ ] to EtherCAT, [✓] to PDI; Watchdog: [✓] Trigger

Register Watchdog Status Process Data (0x0440:0x0441)

Bit	Description	ECAT	PDI	Reset Value
0	Watchdog Status of Process Data (triggered by SyncManagers) 0: Watchdog Process Data expired 1: Watchdog Process Data is active or disabled	r/-	r/ (w ack)*	0

Register AL Event Request (0x0220:0x0223)

		ESC20 ~~[6:4]~~	ET1100 ~~[6:6]~~	ET1200 ~~[6:5]~~	IP Core

Bit	Description	ECAT	PDI	Reset Value
6	Watchdog Process Data: 0: Has not expired 1: Has expired (Bit is cleared by reading Watchdog Status Process Data 0x0440 from PDI)	r/-	r/-	0

The Watchdog is always polled by SSC in the MainLoop() by reading Register 0x440, it is not managed as interrupt.

Figure 84: ESC process data watchdog configuration

The SSC returns a watchdog error (AL Status Code 0x1B “Sync Manager Watchdog”):

1. During the **SAFEOP** → **OP** transition:
   - If the State Machine timeout for the SO transition is reached and no process data was received.
     - Returned in AL_ControlRes()
2. When the Slave is in **OP**:
   - If the watchdog mechanism in use expires ().
     - Returned by ECAT_CheckIfEcatError() if ESC_SM_WATCHDOG_SUPPORTED = 1
     - Returned by ECAT_CheckWatchdog() if ESC_SM_WATCHDOG_SUPPORTED = 0

The following variables are relevant:

- **EcatWdValue** : watchdog time value set by the Master in Register 0x420, is read by the StartInputHandler() function during the PREOP → SAFEOP transition.
- **WdStatusOK** (ESC_SM_WATCHDOG_SUPPORTED = 1): value of Register 0x440.
- **EcatWdCounter** (ESC_SM_WATCHDOG_SUPPORTED = 0): incremented by ECAT_CheckWatchdog(), and reset to zero when new Process Data are received.

17 EtherCAT State Machine

In the EtherCAT state machine 4 mandatory and one optional state is defined. The optional state is the boot state which is indent to be used for firmware updates (see 14.2.2).The State Machine is managed via the **AL_ControlInd()** and **AL_ControlRes()** functions, both defined in ecatslv.c file.

Figure 85 displays the 4 mandatory states and called functions for the transitions.

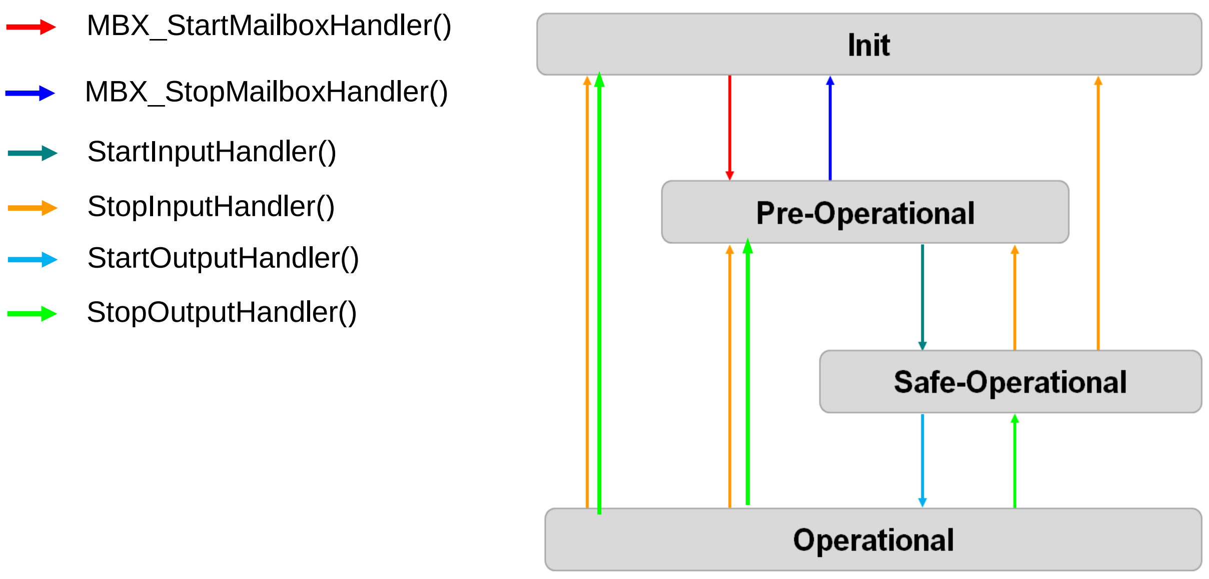


Figure 85: EtherCAT state

In Figure 86 the state machine progress is shown.

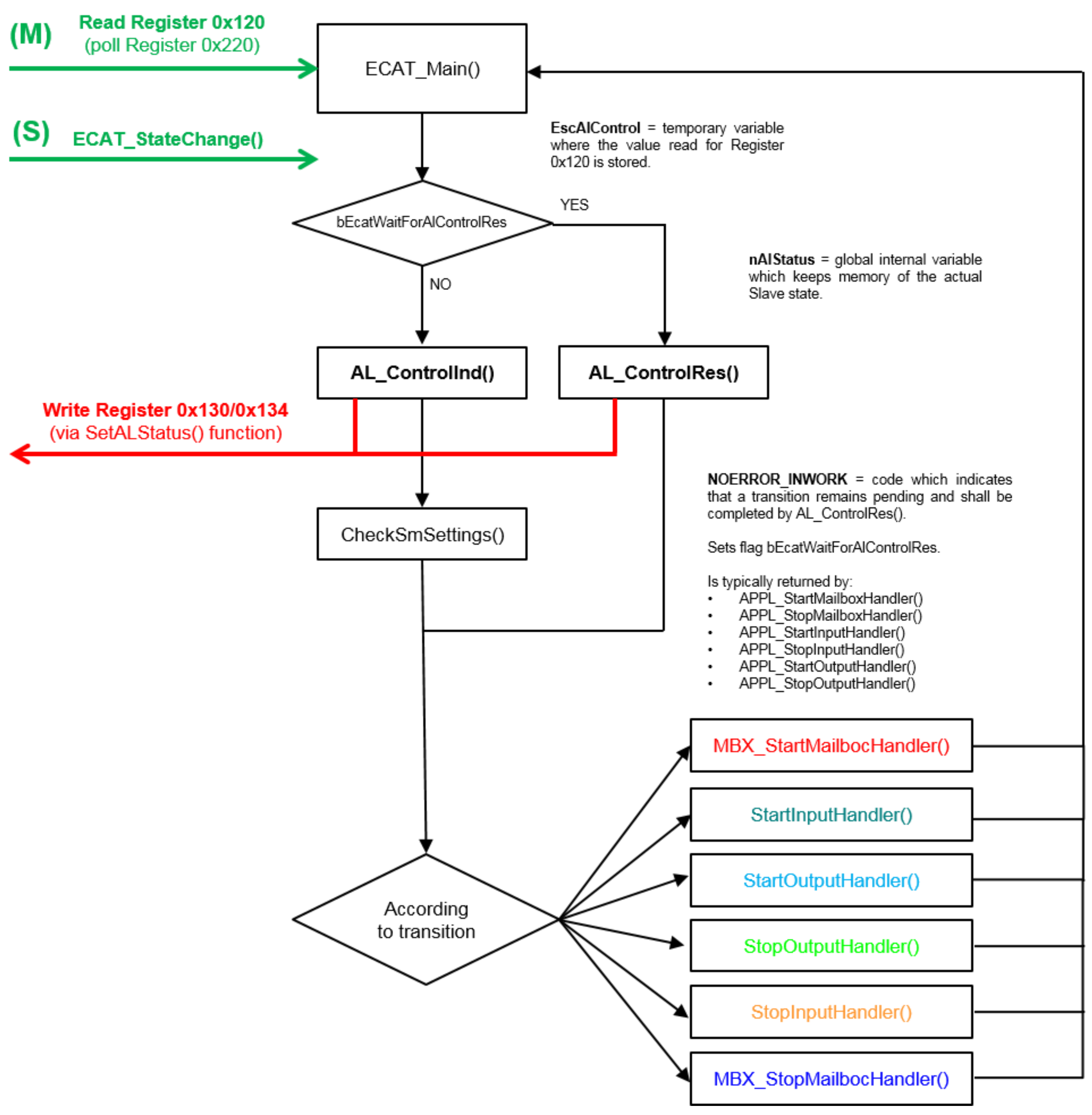

(M)
Read Register 0x120
(poll Register 0x220)
(S)
ECAT_StateChange()
ECAT_Main()
EscAlControl = temporary variable where the value read for Register 0x120 is stored.
bEcatWaitForAlControlRes
YES
NO
nAlStatus = global internal variable which keeps memory of the actual Slave state.
AL_ControlInd()
AL_ControlRes()
Write Register 0x130/0x134
(via SetALStatus() function)
NOERROR_INWORK = code which indicates that a transition remains pending and shall be completed by AL_ControlRes().
Sets flag bEcatWaitForAlControlRes.
Is typically returned by:
• APPL_StartMailboxHandler()
• APPL_StopMailboxHandler()
• APPL_StartInputHandler()
• APPL_StopInputHandler()
• APPL_StartOutputHandler()
• APPL_StopOutputHandler()
CheckSmSettings()
According to transition
MBX_StartMailbocHandler()
StartInputHandler()
StartOutputHandler()
StopOutputHandler()
StopInputHandler()
MBX_StopMailbocHandler()

Figure 86: ESM progress

MBX_StartMailboxHandler()

Check mailbox SyncManager (SM0 and SM1) settings

Activate mailbox SyncManager	HW_EnableSyncManChannel()
Set global variable:	bMbxRunning
Call Application Interface function:	*APPL_StartMailboxHandler()*

MBX_StopMailboxHandler()

Deactivate mailbox SyncManager	HW_DisableSyncManChannel()
Free mailbox Queue buffer	
Clear global variable:	bMbxRunning
Call Application Interface function:	*APPL_StopMailboxHandler()*

StartInputHandler()

Check process data SyncManger settings (SM2 and SM3)

Check distributed clocks settings (if enabled)	
Setup process data watchdog (if enabled)	
Activate output and input process data SyncManger	HW_EnableSyncManChannel()
Set AL Event Mask (register 0x204:0x207)	
Set global variable:	bEcatInputUpdateRunning
Call Application Interface function:	*APPL_StartInputHandler()*

StopInputHandler()

Deactivate input and output process data SyncManger	HW_DisableSyncManChannel()
Reset AL Event Mask (register 0x204:0x207)	
Clear global variable:	bEcatInputUpdateRunning
Call Application Interface function:	*APPL_StopInputHandler()*

StartOutputHandler()

Set global variable:	bEcatOutputUpdateRunning
SM/DC Timing	
Call Application Interface function:	*APPL_StartOutputHandler()*

StopOutputHandler()

Clear global variable:	bEcatOutputUpdateRunning
Call Application Interface function:	*APPL_StopOutputHandler()*

17.1 Transition Examples

Examples for an accepted and rejected transition are shown in Figure 87 and Figure 88.

The general sequence is:

1. The master writes a new requested state (e.g. 0x04 = SafeOP) into 0x0120 “AL Control” register, then starts cyclically polling 0x0130 “AL Status” register
2. The SSC, which cyclically polls 0x0220 “AL Event Request” register, detects the new state transition request
3. The SSC calls the general purpose handler function for the requested transition, which in turn calls the corresponding application API (in the example StartInputHandler() and APPL_StartInputHandler(), respectively)
4. According to the calculation results of these functions, the SSC confirms or refuses the requested state transition by writing the new current state into 0x0130 “AL Status” register (and, in case of refusal, the corresponding error code into 0x0134 “AL Status Code” register)
5. The master, which is polling 0x0130 “AL Status” register, detects the transition result

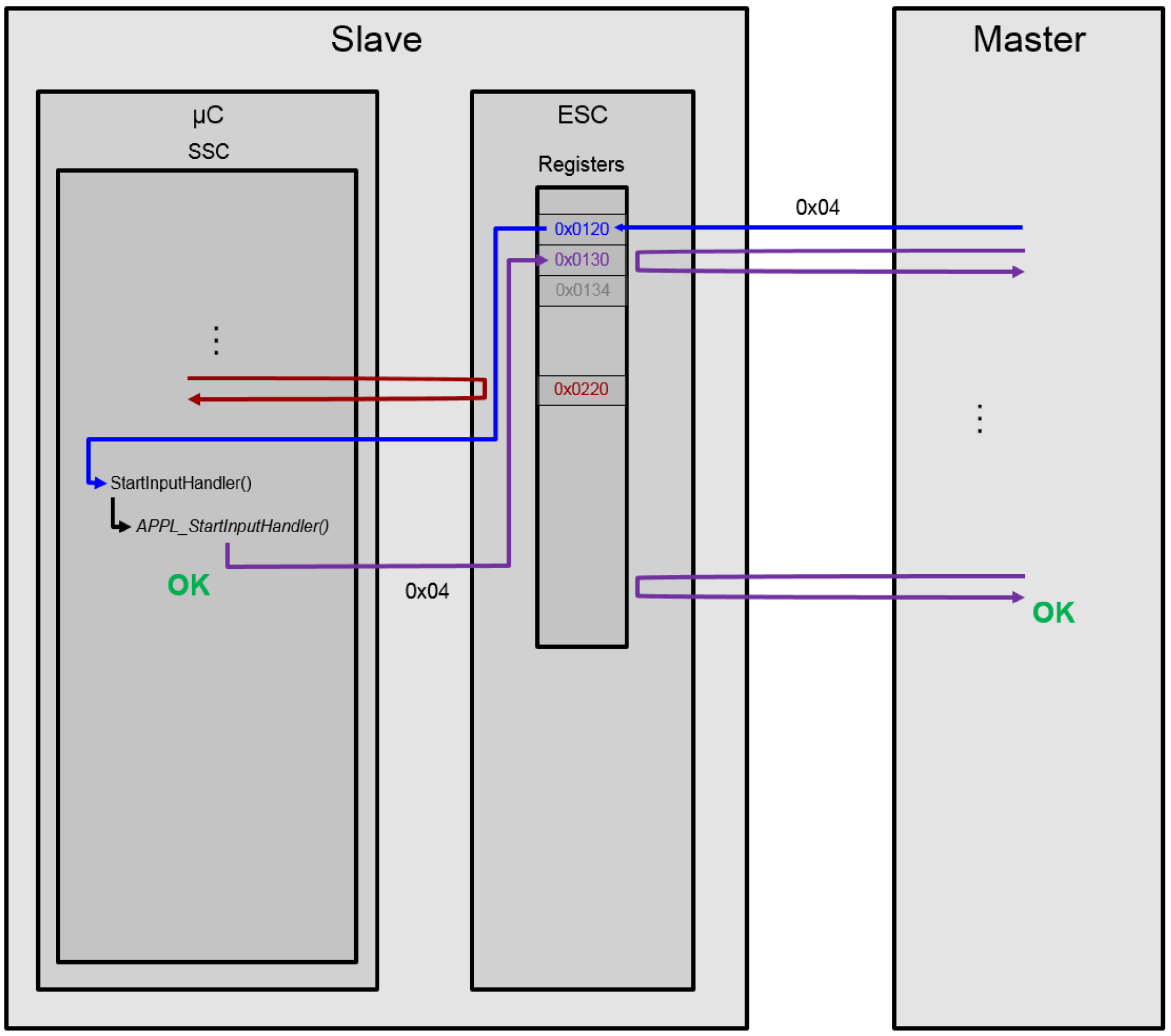


Figure 87: Accepted ESM example

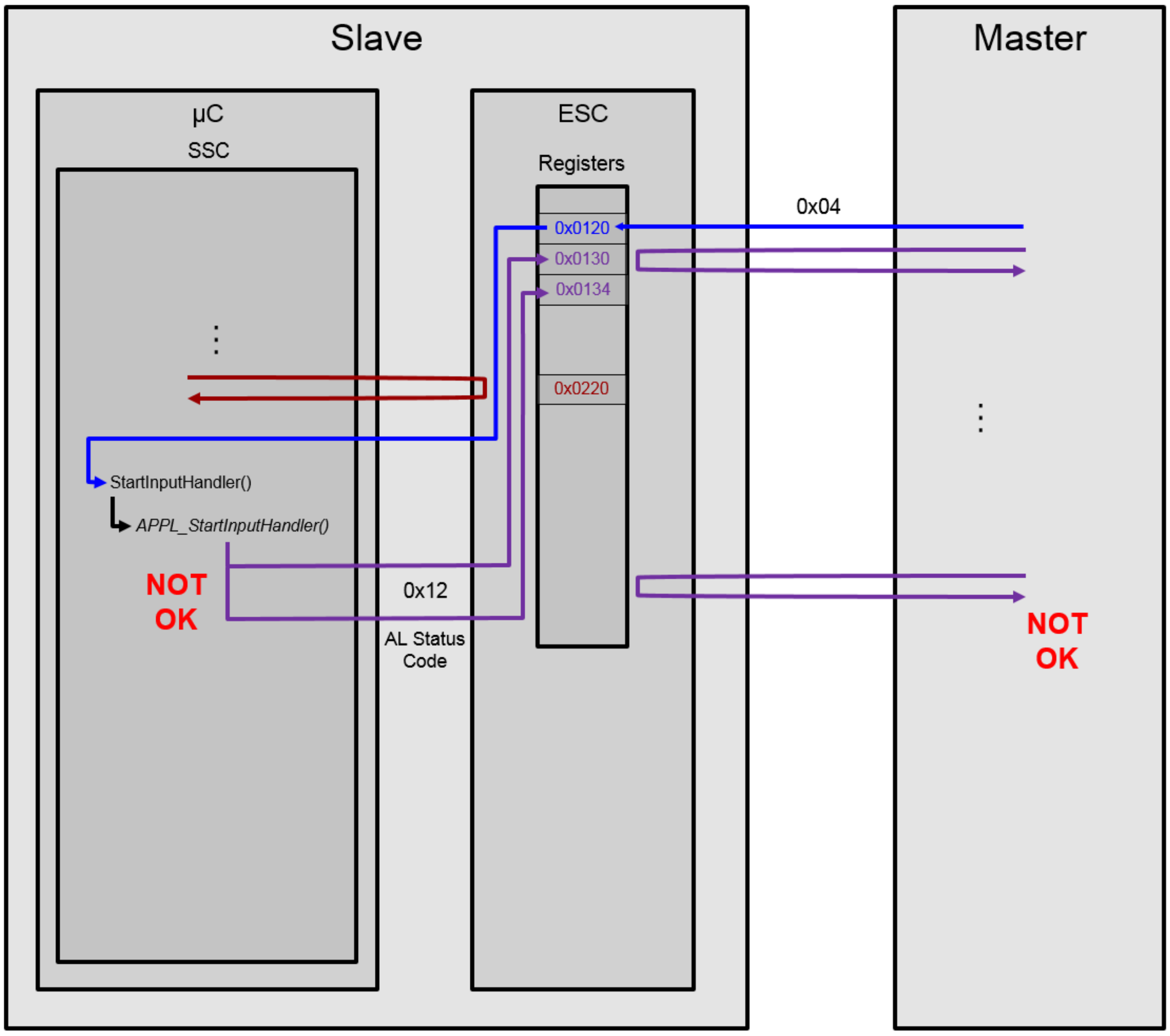


Figure 88: Rejected ESM example

17.2 Sync Manager

The Sync Managers (SM) are used to exchange the process data and mailbox data between the slave and master application. The assignment is follows:

SM0 : mailbox out (Master to Slave)

SM1: mailbox in (Slave to Master)

SM2: process data out (Master to Slave)

SM3: process data out (Slave to Master)

If no mailbox is supported SM0 and SM1 are used for process data exchange and if one of the process data directions is not used the corresponding Sync Manager is disabled. In Table 27 the corresponding registers are listed.

Table 27: Sync Manager Registers

SM0	SM1	SM2	SM3	Description
0x800	0x808	0x810	0x818	Physical Start Address
0x802	0x80A	0x812	0x81A	Length
0x804	0x80C	0x814	0x81C	Control Register
0x805	0x80D	0x814	0x81D	Status Register
0x806	0x80E	0x816	0x81E	Activate

SM0	SM1	SM2	SM3	Description
0x807	0x80F	0x817	0x81F	PDI Control

Usually a SyncManager which is enabled by the Master is also activated by the Slave, and vice-versa a SyncManager which is disabled by the Master is also deactivated by the Slave.

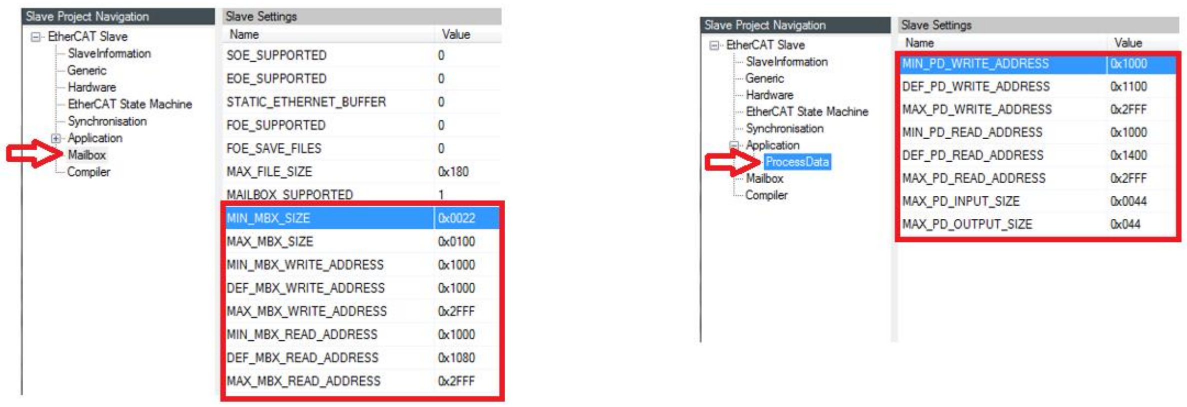
Disabling a SyncManager on Slave side without a corresponding deactivation by the Master happens only as error reaction mechanism, when the Slave spontaneously performs a backward transition due to internal reasons

SyncManagers are checked by 2 functions, both called by AL_ControlInd() during a state transition:

CheckSmSettings() checks the basic SyncManager settings like Address, Length, Flags (all SMs) In case of error, it returns the AL Status Codes:
0x17 “Invalid sync manager configuration” (Start Address and Length not compatible with µC architecture)
0x16 “Invalid mailbox configuration” or 0x15 “Invalid mailbox configuration (bootstrap)” (Mailbox SM settings)
0x1D “Invalid Output Configuration” or 0x1E “Invalid Input Configuration” (Process Data SM settings).
This function checks also if the maximum physical size of the ESC DPRAM is exceeded. In case of error AL Status Code
0x14 “No valid firmware” is returned.

StartInputHandler() checks if the SyncManagers overlap (only Process Data SMs). In case of error, it returns AL Status Codes:
0x1D “Invalid Output Configuration” or
0x1E “Invalid Input Configuration”.

Check is performed by comparing settings sent by the Master via Init Commands with the software constants in the stack (Figure 89).



Name	Value
SOE_SUPPORTED	0
EOE_SUPPORTED	0
STATIC_ETHERNET_BUFFER	0
FOE_SUPPORTED	0
FOE_SAVE_FILES	0
MAX_FILE_SIZE	0x180
MAILBOX_SUPPORTED	1
MIN_MBX_SIZE	0x0022
MAX_MBX_SIZE	0x0100
MIN_MBX_WRITE_ADDRESS	0x1000
DEF_MBX_WRITE_ADDRESS	0x1000
MAX_MBX_WRITE_ADDRESS	0x2FFF
MIN_MBX_READ_ADDRESS	0x1000
DEF_MBX_READ_ADDRESS	0x1080
MAX_MBX_READ_ADDRESS	0x2FFF

Name	Value
MIN_PD_WRITE_ADDRESS	0x1000
DEF_PD_WRITE_ADDRESS	0x1100
MAX_PD_WRITE_ADDRESS	0x2FFF
MIN_PD_READ_ADDRESS	0x1000
DEF_PD_READ_ADDRESS	0x1400
MAX_PD_READ_ADDRESS	0x2FFF
MAX_PD_INPUT_SIZE	0x0044
MAX_PD_OUTPUT_SIZE	0x044

Figure 89: Sync Manager settings in the SSC Tool

18 Slave Identification

In case a slave supports an external switch for Explicit Device Identification purposes according to [7], the Requesting ID mechanism shall be implemented. For legacy reasons only, a slave may need to provide the value of the ID selector via Configured Station Alias register 0x0012 (Legacy Mode mechanism). How to support both modes is described in this clause.

18.1 Requesting ID mechanism

To support the recommend ID handling just the define “EXPLICIT_DEVICE_ID” needs to be enabled. The ID value itself is returned by the function “APPL_GetDeviceID()”. The trigger for the function and forwarding to the EtherCAT master is handled by the default SSC.

18.2 Legacy Mode mechanism

To support Legacy Mode handling, the define “ESC_EEPROM_ACCESS_SUPPORT” (if no EEPROM emulation is enabled) shall be set in the SSC. In case of EEPROM emulation, the EEPROM access shown in the example needs to be adapted.

The sequence of legacy ID handling is described in the www.ethercat.org Knowledge Base, an extract of the flowchart is shown in Figure 90.

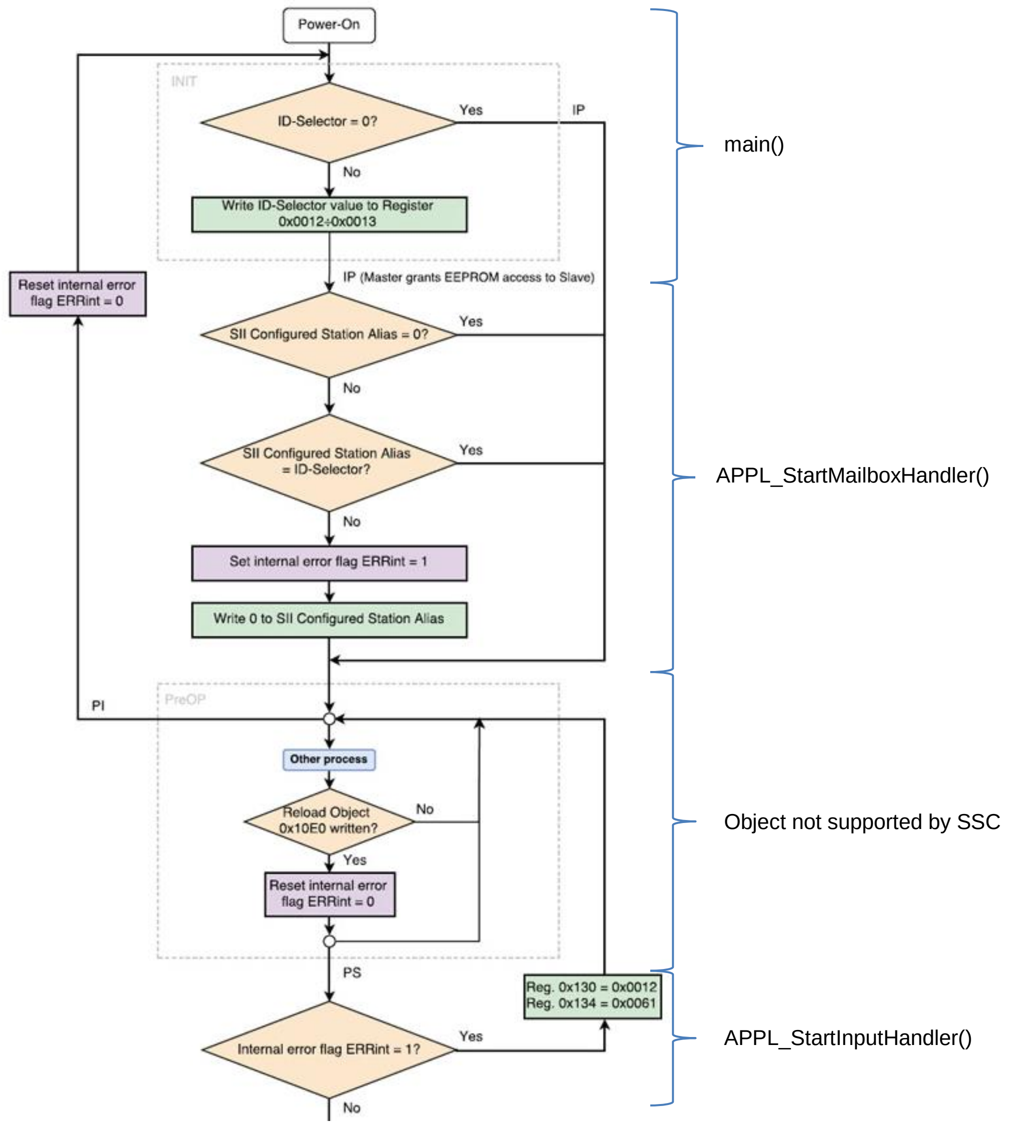

Power-On
INIT
ID-Selector = 0?
Yes
IP
No
Write ID-Selector value to Register 0x0012÷0x0013
IP (Master grants EEPROM access to Slave)
Reset internal error flag ERRint = 0
SII Configured Station Alias = 0?
Yes
No
SII Configured Station Alias = ID-Selector?
Yes
No
Set internal error flag ERRint = 1
Write 0 to SII Configured Station Alias
PI
PreOP
Other process
Reload Object 0x10E0 written?
No
Yes
Reset internal error flag ERRint = 0
PS
Reg. 0x130 = 0x0012
Reg. 0x134 = 0x0061
Internal error flag ERRint = 1?
Yes
No
main()
APPL_StartMailboxHandler()
Object not supported by SSC
APPL_StartInputHandler()

Figure 90: Legacy ID handling

Four application functions are involved in the Legacy Mode handling: “main()”, “APPL_StartMailboxHandler()”,“APPL_StopMailboxHandler()” and “APPL_StartInputHandler()”. These functions are all defined in the application files (e.g. “sampleappl.c” if “SAMPLE_APPLICATION” is enabled).Two additional local variables are defined UINT16 DipswitchIdValue (to store the ID value) and BOOL idError (error indication if the ID values does not match).

main():

```
…
    MainInit();

      DipswitchIdValue = 0x30; /*latching the Dipswitch shall only be done
      on power up*/

      if(DipswitchIdValue != 0)
      {
            /*Write the ID value to register 0x12 (Configured Station
Alias)*/
            HW_EscWriteWord(DipswitchIdValue,0x12);
      }

    bRunApplication = TRUE;
    do
    {
        MainLoop();
…
```

APPL_StartMailboxHandler:

```
UINT16 APPL_StartMailboxHandler(void)
{
      UINT16 SiiIDValue = 0;
      ESC_EepromAccess(0x4,1,&SiiIDValue,ESC_RD);

      if((SiiIDValue != 0) && (SiiIDValue != DipswitchIdValue))
      {
            /*reset SII ID value in case of not matching ID values*/
            SiiIDValue = 0;
            ESC_EepromAccess(0x4,1,&SiiIDValue,ESC_WR);

            idError = TRUE;
      }
      else
      {
            idError = FALSE;
      }
    return ALSTATUSCODE_NOERROR;
}
```

APPL_StopMailboxHandler:

```
UINT16 APPL_StopMailboxHandler(void)
{
    idError = FALSE; /*clear the error indication on PreOP-Init
transition*/
    return ALSTATUSCODE_NOERROR;
}
```

APPL_StartInputHandler:

```
UINT16 APPL_StartInputHandler(UINT16 *pIntMask)
{
      if(idError == TRUE)
      {
            return 0x61; /*AL Status Error Code ID values not match*/
      }
      return ALSTATUSCODE_NOERROR;
}
```

Appendix

Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

Beckhoff's branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!
The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: http://www.beckhoff.com
You will also find further documentation for Beckhoff components there.

Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany

phone:	+ 49 (0) 5246/963-0
fax:	+ 49 (0) 5246/963-198
e-mail:	info@beckhoff.com
web:	www.beckhoff.com

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:
world-wide support
design, programming and commissioning of complex automation systems
and extensive training program for Beckhoff system components

hotline:	+ 49 (0) 5246/963-157
fax:	+ 49 (0) 5246/963-9157
e-mail:	support@beckhoff.com

Beckhoff Service

The Beckhoff Service Center supports you in all matters of after-sales service:
on-site service
repair service
spare parts service
hotline service

hotline:	+ 49 (0) 5246/963-460
fax:	+ 49 (0) 5246/963-479
e-mail:	service@beckhoff.com

EtherCAT Technology Group (ETG) Headquarters

Phone: +49 (911) 540 5620
Fax: +49 (911) 540 5629
Email: info@ethercat.org
Internet: www.ethercat.org