

# XMC4800

# EtherCAT APP SSC

# Firmware Update

# Slave Example

## Getting Started

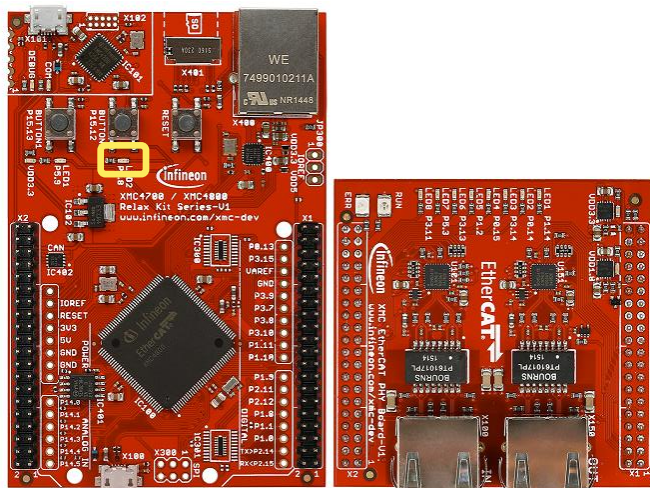
## Version 1.0



- 1 Overview and requirements
- 2 Setup
- 3 Short overview – boot modes
- 4 Architecture
- 5 Implementation of the application
- 6 Implementation of the bootloader
- 7 How to test – using TwinCAT3 as host

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# Overview



This example demonstrates the implementation of a EtherCAT slave node which is capable doing firmware updates via FoE (File over EtherCAT). This example here is based on the basic example described inside „Getting Started - XMC4800\_Relax\_EtherCat\_APP\_Slave\_SSC Example\_V2.2.pdf“.

Before you proceed with this example, make sure to have a solid understanding of the basic documentation first.

Here you will learn, to configure XMC4800 having two independent flash executables installed and the flash organized in four independent partitions. You will see how to generate a firmware update binary within DAVE4, add the firmware update functionality to the slave stack code and implement CRC32 checking on the binary. Finally you will see the firmware update functionality in action using TwinCAT.

# Requirements



XMC4800 Relax EtherCAT Kit



RJ45 Ethernet Cable



Windows Laptop installed

- DAVE v4 (Version4.3.2 or higher)
- TwinCAT2 or TwinCAT3 Master PLC
- Slave Stack Code Tool



Micro USB Cable (Debugger connector)

# Requirements - free downloads



TwinCAT2 (30 day trial; 32bit Windows only)

Link: [Download TwinCAT2](#)

or



TwinCAT3 (no trial period; usability limited; 32bit and 64bit Windows)

Link: [Download TwinCAT3](#)

**ATTENTION:** According to our experience TwinCAT is best compatible with Intel™ ethernet chipset.

For details on compatibility with your hardware, additional driver and general installation support please get into contact with your local BECKHOFF support.

# Requirements - free downloads



DAVE (v4.3.2 or higher)

Link: [Download DAVE \(Version 4\)](#)



EtherCAT Slave Stack Code Tool  
(ETG membership obligatory)

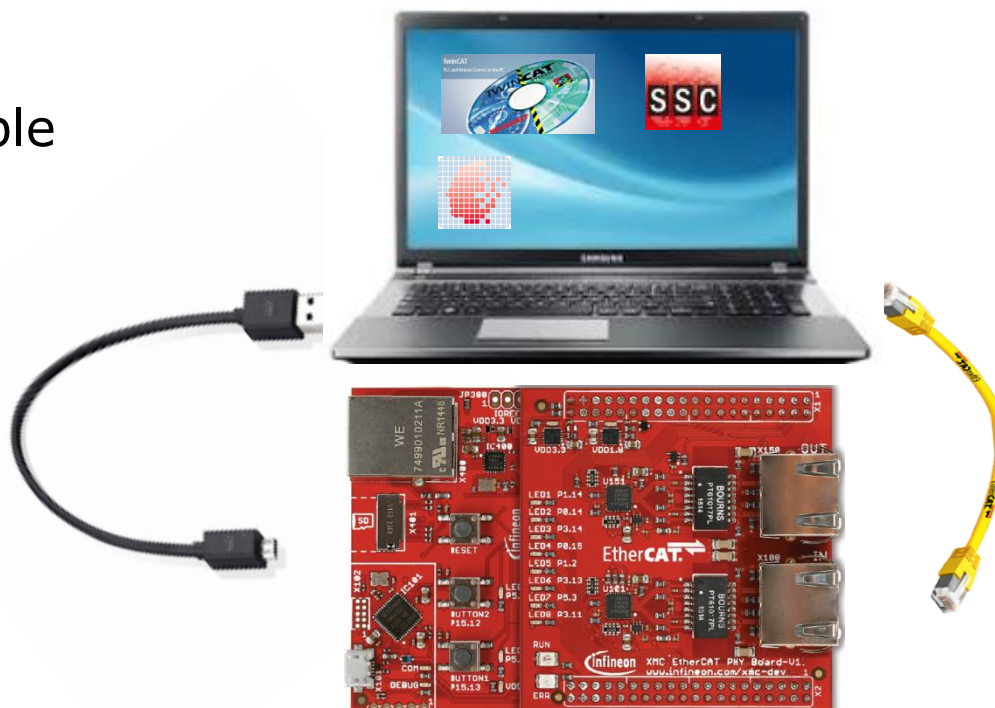
Link: [Slave Stack Code Tool](#)

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# Setup – Hardware

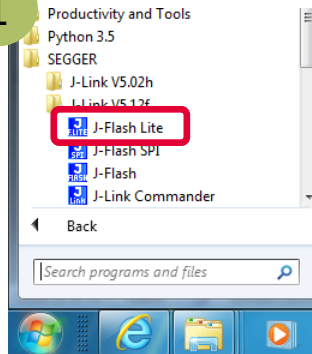
Micro USB cable  
Debugger  
connected to  
X101 debug  
connector



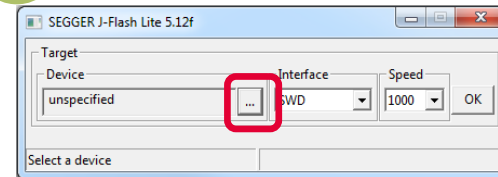
Ethernet Cable  
connected to  
IN-port

# Setup – Cleanup flash of XMC4800

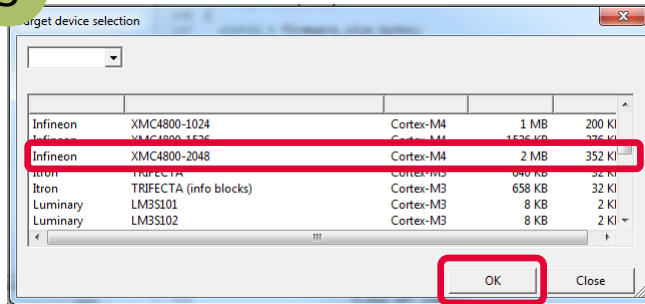
1



2

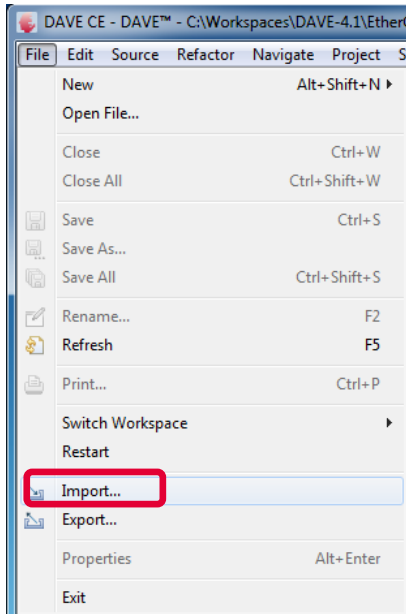


3

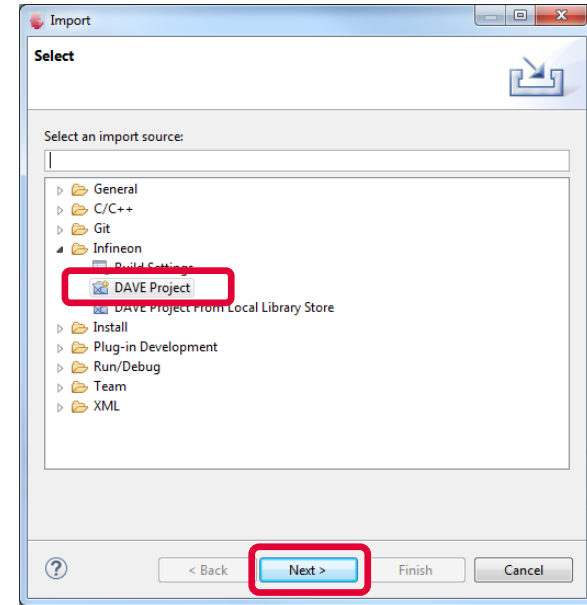


# Setup – Import the two example projects into DAVE

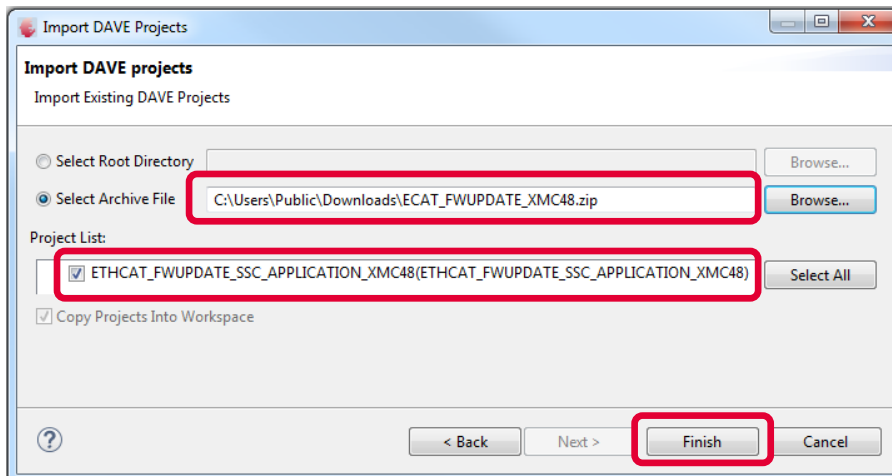
1



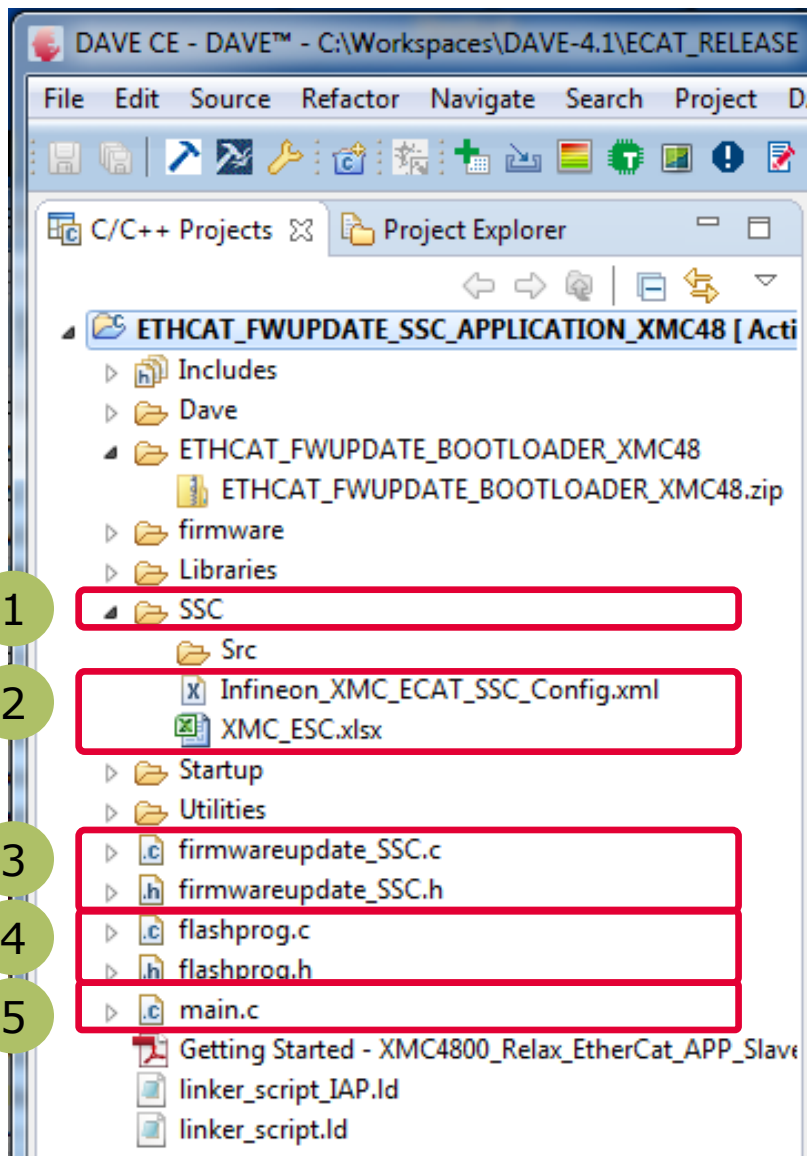
2



3



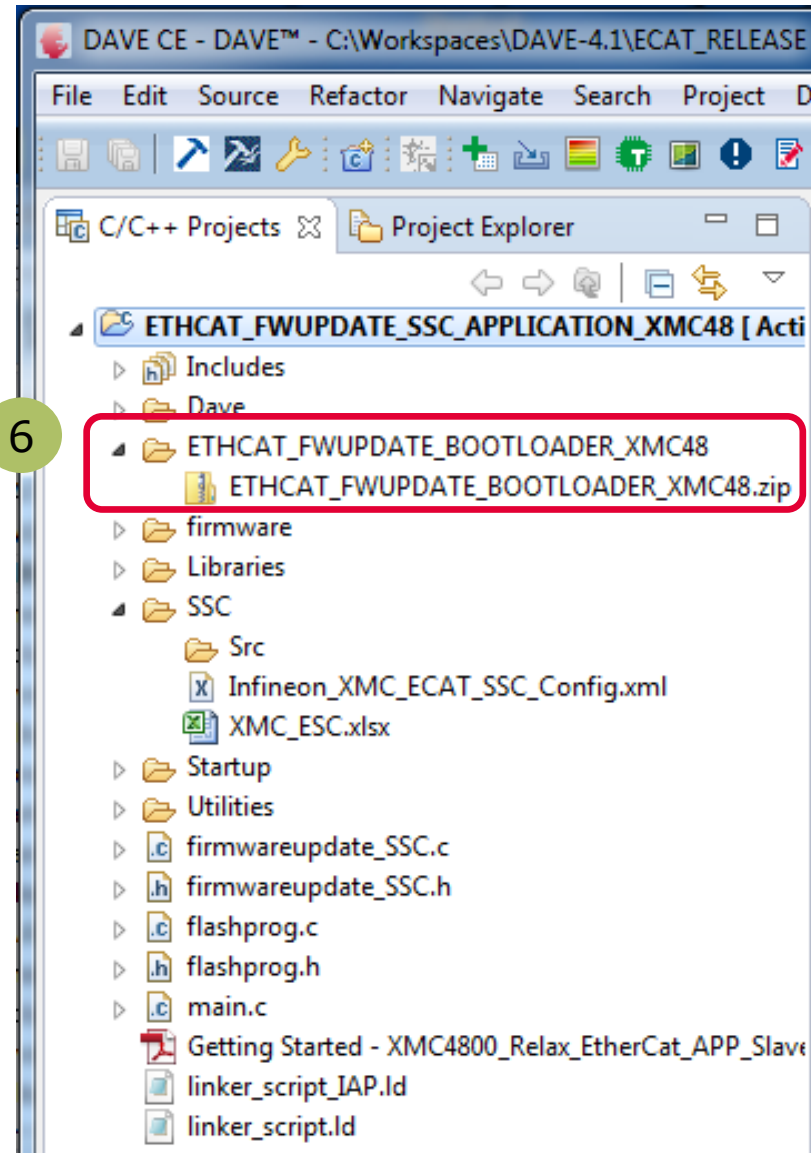
# Setup – Imported application example



After the project import, you will find the project for application executable:

- 1 The project is nearly complete for build. It only misses the EtherCAT slave stack code. For these files, the Src folder has been already prepared.
- 2 The EtherCAT slave stack code for the XMC4800 is generated by configuration files. These configuration files are included in the project already.
- 3 Firmware update example implementation; called from SSC
- 4 Utility files to support the flash programming
- 5 Main.c of EtherCAT™ application

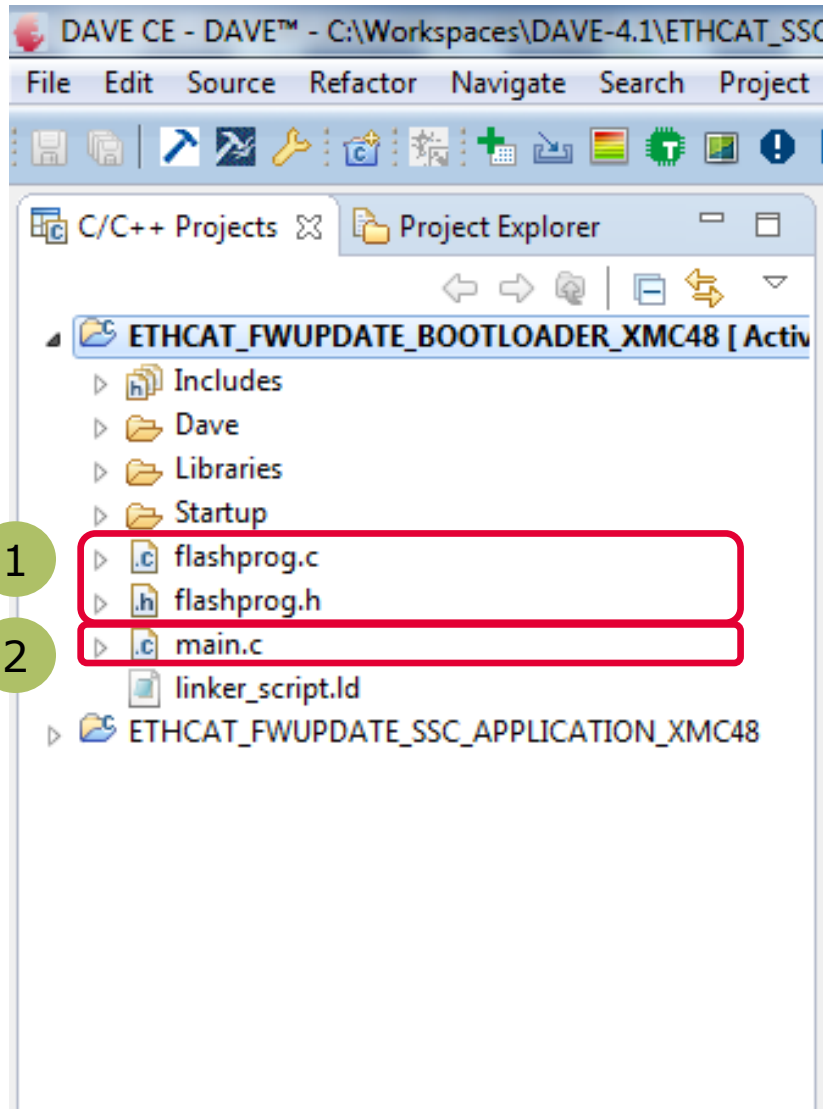
# Setup – Imported application example



6 The zip-file to import the 2nd project you find in the application project you just have imported.

Import this project in the same way you just have imported the application project.

# Setup – Imported bootloader example



After the project import you will find the project for bootloader executable:

- 1 Utility files to support the flash programming
- 2 Main.c of bootloader application

The following slides show the architecture, how the applications interact and the essential implementation details behind bootloader and application executable.

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Inside the setup section of this documentation, you already imported two independent projects into DAVE. The executables resulting from these projects have to be stored inside flash and are interacting with each other:

**1. Application executable**

(ETHCAT\_FWUPDATE\_SSC\_APPLICATION\_XMC48)

Executes EtherCAT™ slave stack

Downloads new firmware into backup partition via FoE

**2. Bootloader executable**

(ETHCAT\_FWUPDATE\_BOOTLOADER\_XMC48)

Checks the availability of new firmware inside backup partition

If available, updates application executable with new firmware

→ XMC supports a variety of boot modes for execution of independent executables. See the following slides to get a short overview on the boot modes which are used inside this example.



Table 27-2 System reset boot modes

SWCON[3:0]	Boot mode
0000 <sub>B</sub>	Normal
0001 <sub>B</sub>	ASC BSL
0010 <sub>B</sub>	BMI
0011 <sub>B</sub>	CAN BSL
0100 <sub>B</sub>	PSRAM boot
1000 <sub>B</sub>	ABM-0
1100 <sub>B</sub>	ABM-1
1110 <sub>B</sub>	Fallback ABM

XMC4800 supports different boot modes.

1 These boot modes can be selected by driving the boot mode pins (JTAG TCK TMS) with appropriate logic levels and issuing a system or power on reset:  
Normal, ASC BSL (UART bootstrap), CAN BSL (CAN bootstrap), BMI

2 By preparing a header information inside flash and issuing a system reset (via software) these boot modes can be used in addition. These boot modes cannot be entered with power on reset:

Alternative Boot modes (ABM-0/ABM-1), PSRAM boot, FallbackABM

# Boot modes – normal and alternative boot mode 0

Table 27-2 System reset boot modes

SWCON[3:0]	Boot mode
0000 <sub>B</sub>	Normal
0001 <sub>B</sub>	ASC BSL
0010 <sub>B</sub>	BMI
0011 <sub>B</sub>	CAN BSL
0100 <sub>B</sub>	PSRAM boot
1000 <sub>B</sub>	ABM-0
1100 <sub>B</sub>	ABM-1
1110 <sub>B</sub>	Fallback ABM

For this example these boot modes are used:

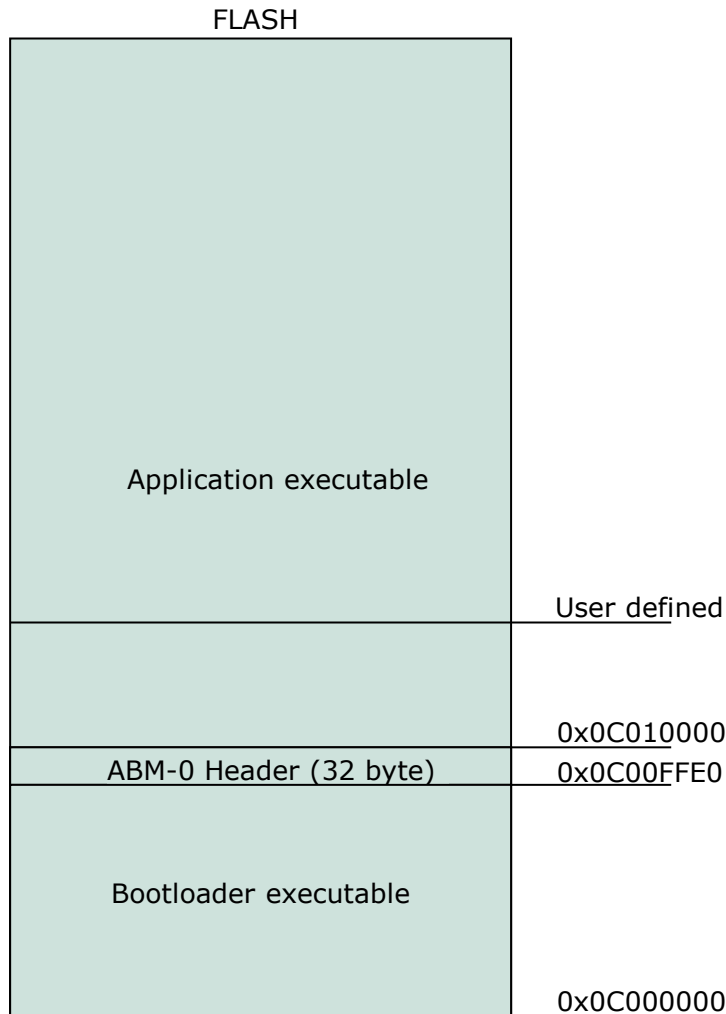
## **Normal boot mode (after system or power on reset)**

An application located at start of the flash is executed.

## **Alternative boot mode 0 (after system reset)**

An application located at a user defined address inside flash is executed. The address is defined inside the „ABM Header“.

ABM Header must be located at last 32bytes (0x0C00FEE0) of the first 64kB physical sector inside flash.



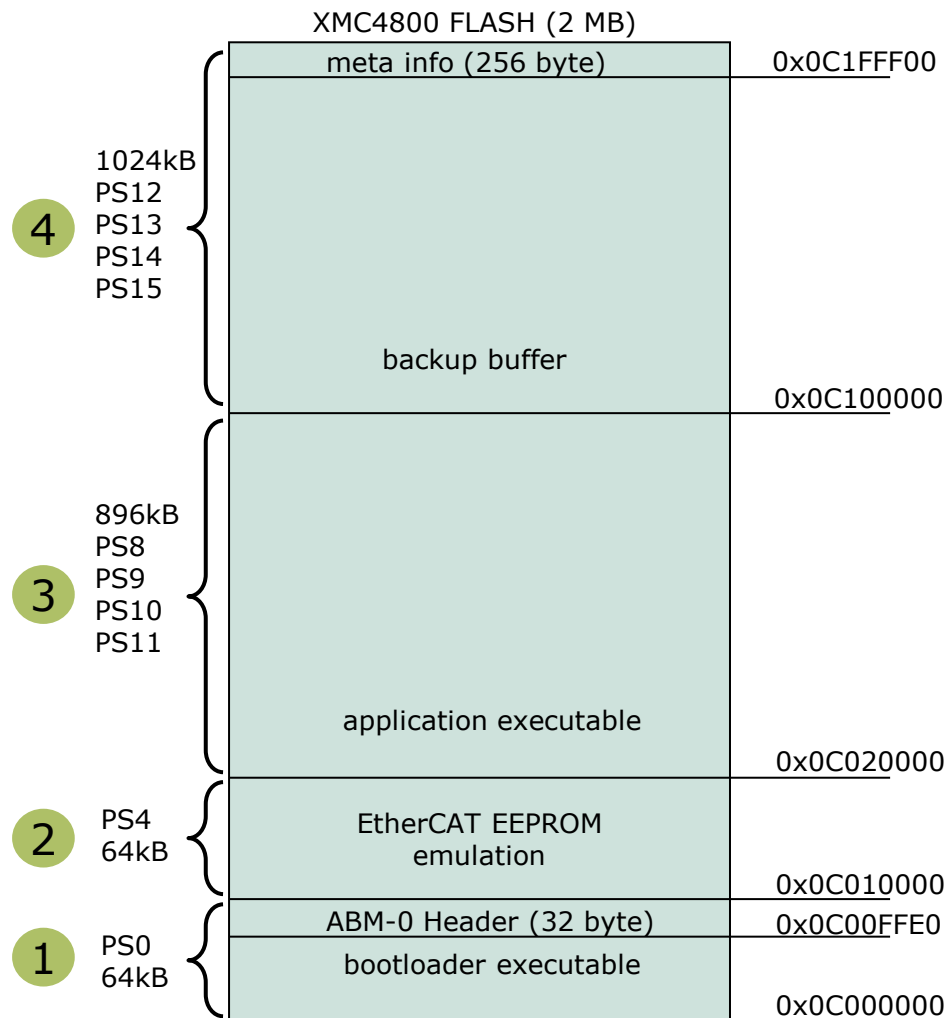
**The application executable** is located at a flash address defined inside ABM-0 Header(@0x0C00FFE0):

- Application is never executed directly after power on reset
- Application execution can only be triggered by a system reset from bootloader executable

**The bootloader executable** is located at flash address 0x0C000000:

- Bootloader execution is triggered by power on or system reset .
- Bootloader starts the application executable or proceeds with bootloader functionality.

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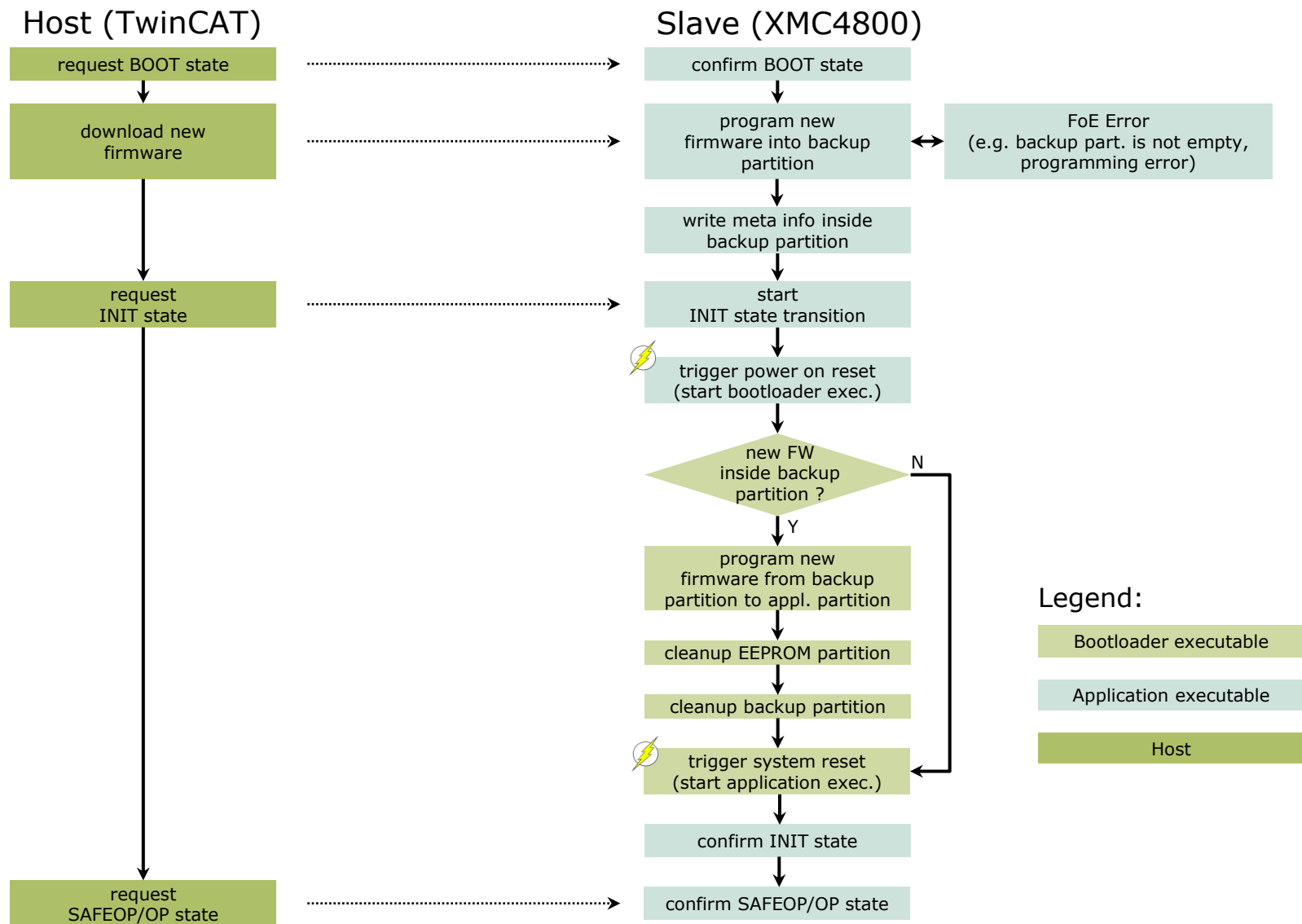
**1** Bootloader executable is always executed first after each power on reset. Checks availability of new firmware inside backup buffer. If new firmware is available, it is copied from backup buffer to application executable partition incl. error checks. After cleaning of backup and EEPROM emulation partition, restarts the device with application executable.

**2** EtherCAT EEPROM emulation. If empty, is initialized by ECAT\_SSC APP with the slaves default settings during first init.

**3** Application executable implements EtherCAT™ SSC stack. Downloads new firmware to backup partition via FoE incl. error checks. If success, issues power on reset to trigger reprogramming of application by bootloader executable.

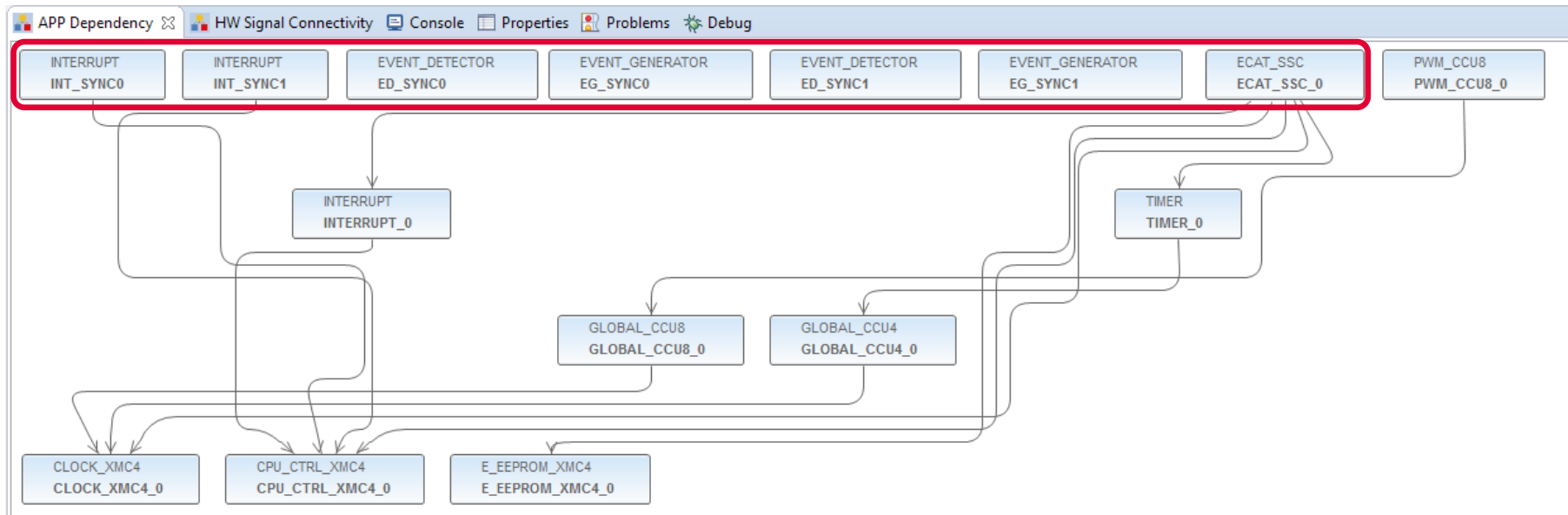
**4** Backup buffer used to store new firmware by application executable. Last flash page is reserved for meta info. Today only size of new FW is stored inside meta info. Backup buffer is checked by bootloader to reprogram application executable after integrity of firmware is proven.

# Architecture – Host/Slave interaction states for firmware update



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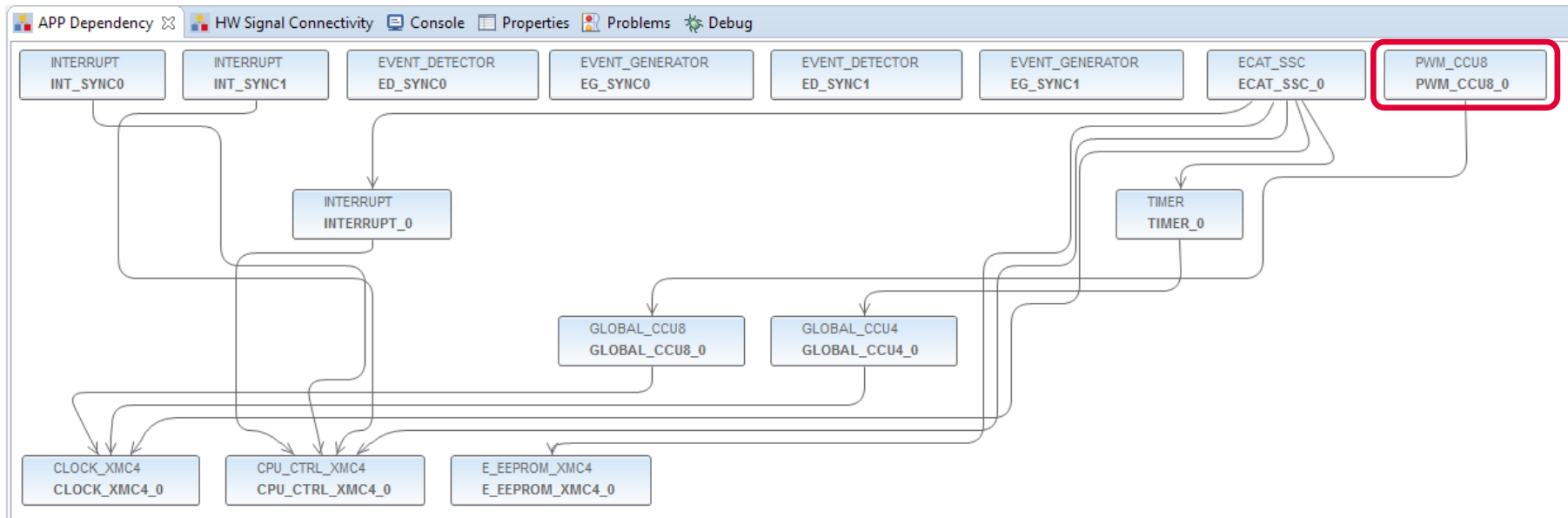
# Application – Overview on used APPs



Same like for the basic example, the ECAT\_SSC APP assigns the system resources (automatically done by DAVE using the respective lower level apps) and pins (by manual configuration) to setup a proper EtherCAT communication. The EVENT\_DETECTOR, EVENT\_GENERATOR and INTERRUPT APPs are used to connect the sync\_out\_0 and sync\_out\_1 of the ECAT\_SSC APP to the interrupt service routines of the SSC-stack.



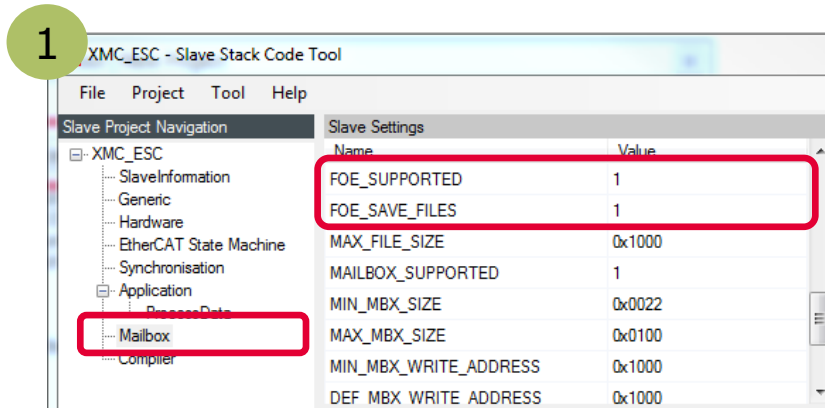
# Application – Overview on used APPs



The basic example used PWM\_CCU8 APP to control the dimming level of the LED2 on your Relax Kit by TwinCAT host. This example uses PWM\_CCU8 APP to set a constant flashing rate of either 2Hz or 20Hz to LED2. The two different application binaries are then used to test firmware update functionality. This allows to visualize the successful firmware update by just checking the flash rate of LED2.

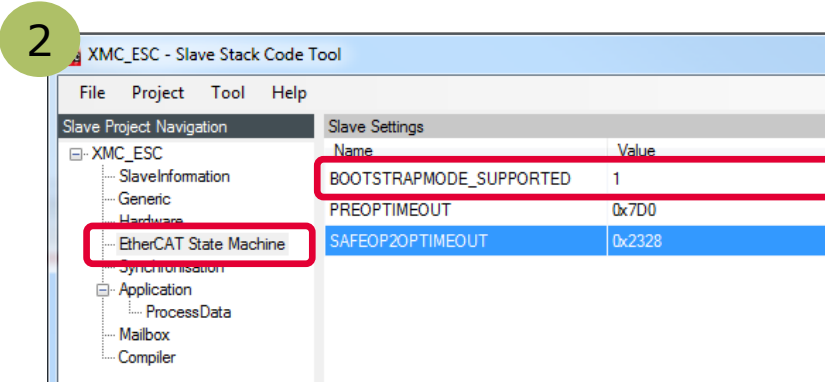
# Application – SSC Tool

## EtherCAT™ stack configuration



1 Enable FoE support including saving of files

2 Enable bootstrap mode support



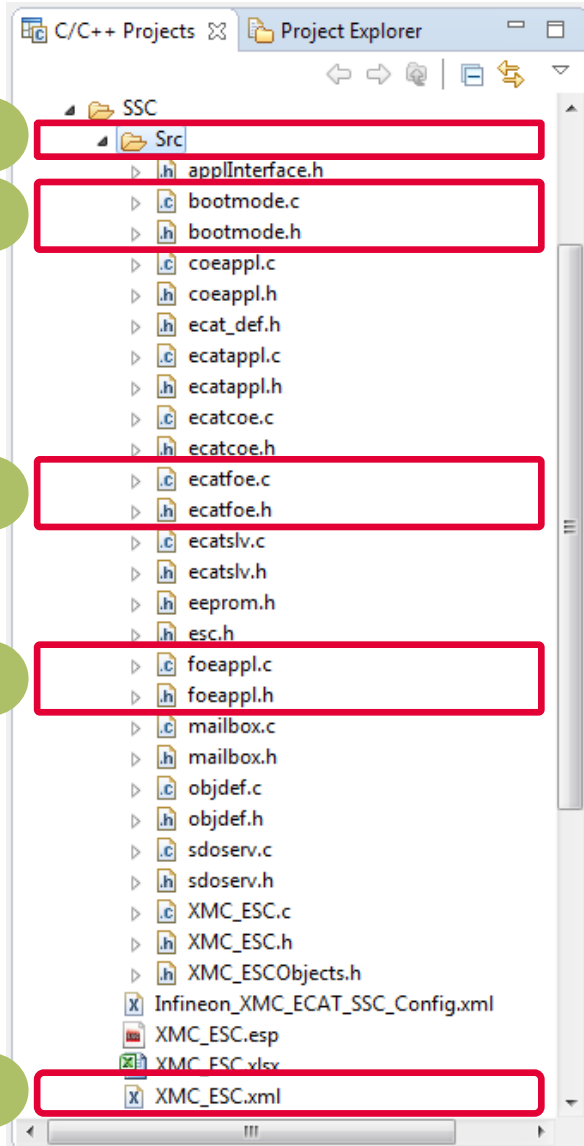
→ To generate the slave stack code and ESI-file with this configuration, please see the documentation of the basic example.

# Application – SSC Tool

## Find and use your result

After the code generation you find the respective files inside the project:

- 3 Check the availability of the generated slave stack code inside Src folder
- 4 Because you configured FoE and bootstrap mode, these files are added to slave stack code.
- 5 Check the availability of the ESI-file and download to the host by these 3 steps:
  1. Stop TwinCAT System Manager
  2. Copy the ESI file to resp. destination for TwinCAT2:  
*C:\TwinCAT\Io\EtherCAT*  
for TwinCAT3:  
*C:\TwinCAT\3.1\Config\Io\EtherCAT*
  3. Restart TwinCAT System Manager to start re-work of the device description cache.



# Application – Extend slave stack code with calls into your application

Inside the generated file *XMC\_ESC.c* the function *APPL\_Application* is implemented. This function is executed cyclic and implements the application specific code

- A) ... from mainloop or
- B) ... if synchronisation is active from ISR

Inside *main.c* of the example, the function *void process\_app(TOBI7000 \*OUT\_GENERIC, TOBI6000 \*IN\_GENERIC);* implements the mapping of the input/output data to buttons and LEDs. In addition it checks if a firmware update has finished. If yes, it triggers a system reset to start bootloader executable. Modify the function *APPL\_Application* to call *process\_app* in the following way:

Originally generated code:

```
//////////////////////////////////////////////////////////////////
/**
\brief   This function will called from the synchronisation ISR
        or from the mainloop if no synchronisation is supported
*//////////////////////////////////////////////////////////////////
void APPL_Application(void)
{
#if _WIN32
#pragma message ("Warning: Implement the slave application")
#else
#warning "Implement the slave application"
#endif
}
```



Modified code:

```
//////////////////////////////////////////////////////////////////
/**
\brief   This function will called from the synchronisation ISR
        or from the mainloop if no synchronisation is supported
*//////////////////////////////////////////////////////////////////
void process_app(TOBI7000 *OUT_GENERIC, TOBI6000 *IN_GENERIC);
void APPL_Application(void)
{
    process_app(&OUT_GENERIC0x7000, &IN_GENERIC0x6000);
}
```

# Application – Extend slave stack code with calls into your application

Inside the generated file *XMC\_ESC.c* file the function *APPL\_StopMailboxHandler* is implemented. This function is called when slave is requested to INIT state.

The function *void FWUPDATE\_StateTransitionInit(void)* of the example implementation is called to indicate the slave state changes from BOOT to INIT.

Originally generated code:

```
80 //////////////////////////////////////////////////
81 /**
82  \return    0, NOERROR_INWORK
83
84  \brief     The function is called in the state transition from PREEOP to INIT
85             to stop the mailbox handler. This functions informs the application
86             about the state transition, the application cannot refuse
87             the state transition.
88
89  */////////////////////////////////////////////////
90
91 UINT16 APPL_StopMailboxHandler(void)
92 {
93     return ALSTATUSCODE_NOERROR;
94 }
```



Modified code:

```
81 //////////////////////////////////////////////////
82 /**
83  \return    0, NOERROR_INWORK
84
85  \brief     The function is called in the state transition from PREEOP to INIT
86             to stop the mailbox handler. This functions informs the application
87             about the state transition, the application cannot refuse
88             the state transition.
89
90  */////////////////////////////////////////////////
91 void FWUPDATE_StateTransitionInit(void);
92
93 void APPL_StopMailboxHandler(void)
94 {
95     FWUPDATE_StateTransitionInit();
96     return ALSTATUSCODE_NOERROR;
97 }
```

# Application – Extend slave stack code with calls into your application

1

```
foeappl.c
172 UINT16 FOE_Write(UINT16 MBXMEM * pName, UINT16 nameSize, UINT32 password)
173 {
174     /* firmware update only in boot mode
175      * boot mode active ? */
176     if ( bBootMode )
177     {
178         /* password valid ? */
179         if (password == 0xBEEFBEEF)
180         {
181             /* start firmware update */
182             FWUPDATE_StartDownload();
183             return 0;
184         }
185         else
186         {
187             /* wrong password */
188             return ECAT_FOE_ERRCODE_ILLEGAL;
189         }
190     }
191     else
192     /* no files are stored/accepted */
193     return ECAT_FOE_ERRCODE_DISKFULL;
194 }
195
```

2

```
foeappl.c
219 UINT16 FOE_Data(UINT16 MBXMEM * pData, UINT16 Size)
220 {
221     /* boot mode active ?
222      * -> proceed with firmware update
223      */
224     if ( bBootMode )
225     {
226         /* forward data to firmwareupdate handler */
227         return FWUPDATE_Data(pData, Size);
228     }
229     else
230     /* no other files than firmware data are stored/accepted */
231     return ECAT_FOE_ERRCODE_DISKFULL;
232 }
---
```

3

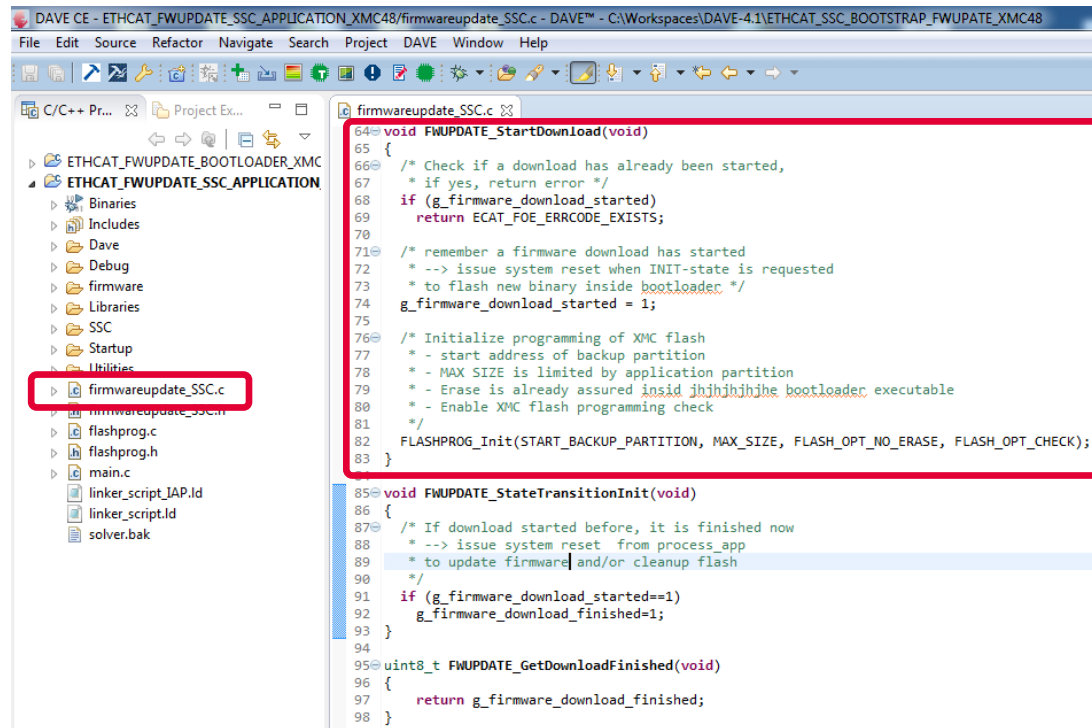
```
foeappl.c
46 #define _FOEAPPL_ 1
47 #include "foeappl.h"
48 #undef _FOEAPPL_
49 #define _FOEAPPL_ 0
50
51 #include "bootmode.h"
52 #include "firmwareupdate_SSC.h"
53
```

Inside the generated file foeappl.c your application specific code for the FoE functionality is implemented.

Every FoE write transaction starts with a call to FOE\_Write and is continued with calls to FOE\_Data. Here you add the calls to the firmware update example implementation:

- 1 Check if BOOT state is active and password matches(optional). If yes, start download by calling example implementation, otherwise return error.
- 2 Check if BOOT state is still active. If yes, forward data to example implementation, otherwise return error.
- 3 Include header file to firmware update example implementation.

# Application – Firmware update example implementation



```
DAVE CE - ETHCAT_FWUPDATE_SSC_APPLICATION_XMC48/firmwareupdate_SSC.c - DAVE™ - C:\Workspaces\DAVE-4.1\ETHCAT_SSC_BOOTSTRAP_FWUPATE_XMC48
File Edit Source Refactor Navigate Search Project DAVE Window Help

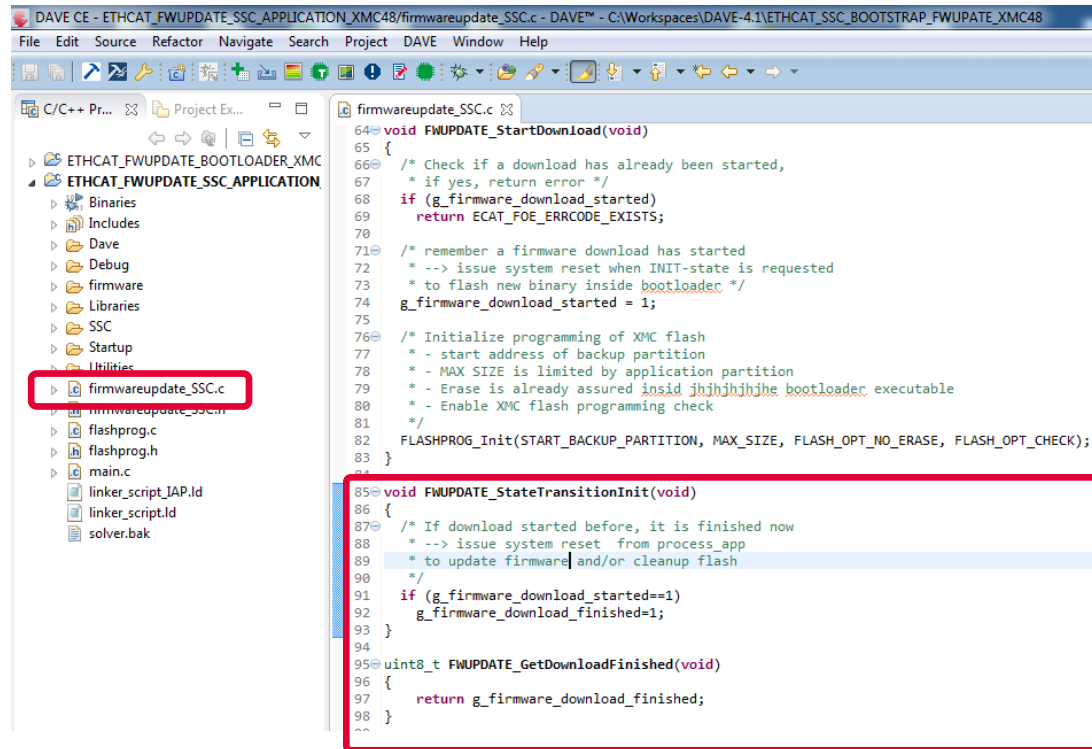
C/C++ Pr... Project Ex...
  ETHCAT_FWUPDATE_BOOTLOADER_XMC
  ▲ ETHCAT_FWUPDATE_SSC_APPLICATION
    Binarie
    Includes
    Dave
    Debug
    firmware
    Libraries
    SSC
    Startup
    Utilities
    firmwareupdate_SSC.c
    firmwareupdate_SSC.h
    flashprog.c
    flashprog.h
    main.c
    linker_script_IAP.ld
    linker_script.ld
    solver.bak

firmwareupdate_SSC.c
64 void FWUPDATE_StartDownload(void)
65 {
66     /* Check if a download has already been started,
67      * if yes, return error */
68     if (g_firmware_download_started)
69         return ECAT_FOE_ERRCODE_EXISTS;
70
71     /* remember a firmware download has started
72      * --> issue system reset when INIT-state is requested
73      * to flash new binary inside bootloader */
74     g_firmware_download_started = 1;
75
76     /* Initialize programming of XMC flash
77      * - start address of backup partition
78      * - MAX SIZE is limited by application partition
79      * - Erase is already assured inside bootloader executable
80      * - Enable XMC flash programming check
81      */
82     FLASHPROG_Init(START_BACKUP_PARTITION, MAX_SIZE, FLASH_OPT_NO_ERASE, FLASH_OPT_CHECK);
83 }

85 void FWUPDATE_StateTransitionInit(void)
86 {
87     /* If download started before, it is finished now
88      * --> issue system reset from process_app
89      * to update firmware and/or cleanup flash
90      */
91     if (g_firmware_download_started==1)
92         g_firmware_download_finished=1;
93 }
94
95 uint8_t FWUPDATE_GetDownloadFinished(void)
96 {
97     return g_firmware_download_finished;
98 }
99
```

***FWUPDATE\_StartDownload*** is called from SSC stack when a new firmware update in BOOT state is initiated. Check if update was already started in the past. In this case return error, because flash is no more clean. If flash is clean, initialize flash programming to store data inside backup partition.

# Application – Firmware update example implementation



```
DAVE CE - ETHCAT_FWUPDATE_SSC_APPLICATION_XMC48/firmwareupdate_SSC.c - DAVE™ - C:\Workspaces\DAVE-4.1\ETHCAT_SSC_BOOTSTRAP_FWUPATE_XMC48
File Edit Source Refactor Navigate Search Project DAVE Window Help

C/C++ Pr... Project Ex...
ETHCAT_FWUPDATE_BOOTLOADER_XMC
  ETHCAT_FWUPDATE_SSC_APPLICATION
    Binaries
    Includes
    Dave
    Debug
    firmware
    Libraries
    SSC
    Startup
    Utilities
    firmwareupdate_SSC.c
    firmwareupdate_SSC.h
    flashprog.c
    flashprog.h
    main.c
    linker_script_IAP.ld
    linker_script.ld
    solver.bak

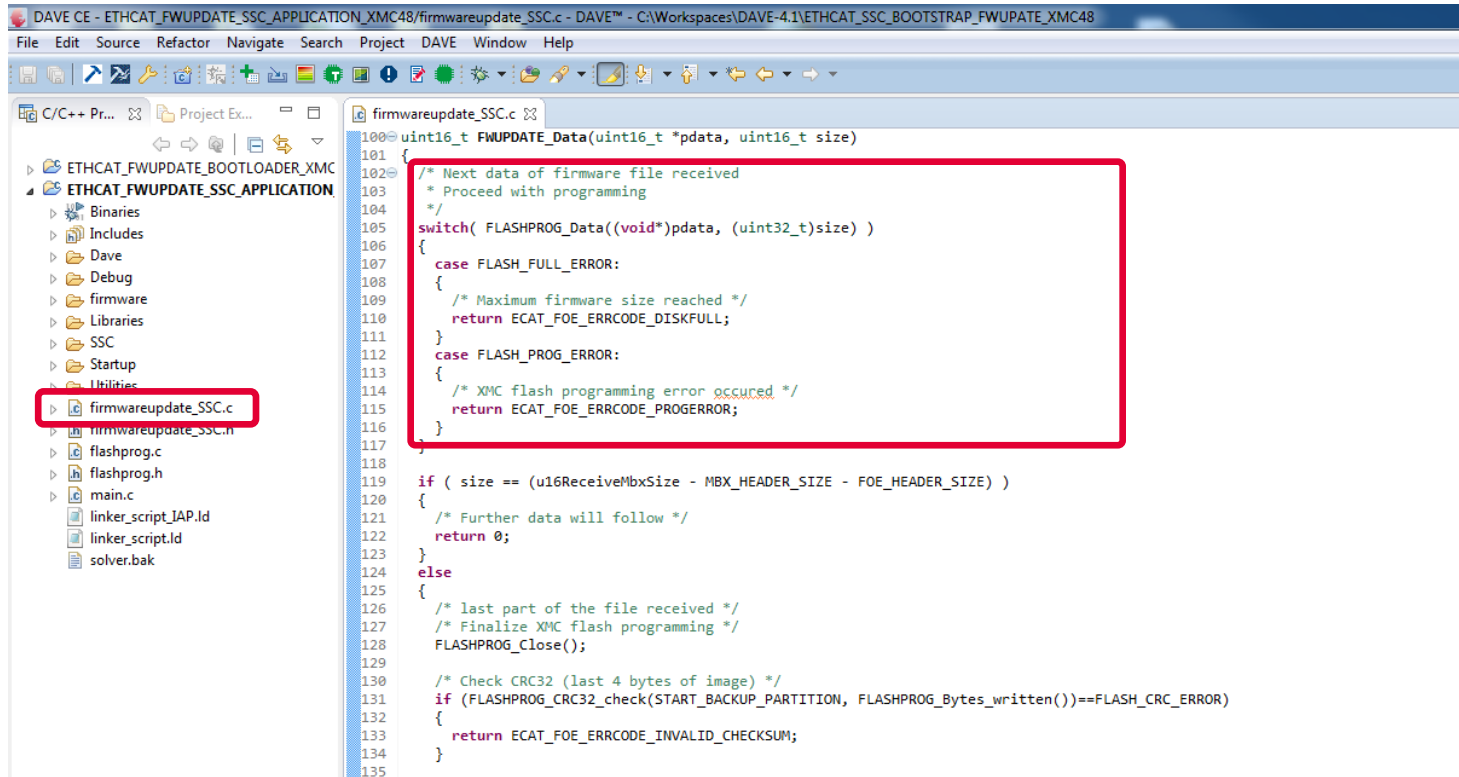
firmwareupdate_SSC.c
64 void FWUPDATE_StartDownload(void)
65 {
66     /* Check if a download has already been started,
67      * if yes, return error */
68     if (g_firmware_download_started)
69         return ECAT_FOE_ERRCODE_EXISTS;
70
71     /* remember a firmware download has started
72      * --> issue system reset when INIT-state is requested
73      * to flash new binary inside bootloader */
74     g_firmware_download_started = 1;
75
76     /* Initialize programming of XMC flash
77      * - start address of backup partition
78      * - MAX SIZE is limited by application partition
79      * - Erase is already assured inside the bootloader executable
80      * - Enable XMC flash programming check
81      */
82     FLASHPROG_Init(START_BACKUP_PARTITION, MAX_SIZE, FLASH_OPT_NO_ERASE, FLASH_OPT_CHECK);
83 }
84
85 void FWUPDATE_StateTransitionInit(void)
86 {
87     /* If download started before, it is finished now
88      * --> issue system reset from process_app
89      * to update firmware and/or cleanup flash
90      */
91     if (g_firmware_download_started==1)
92         g_firmware_download_finished=1;
93 }
94
95 uint8_t FWUPDATE_GetDownloadFinished(void)
96 {
97     return g_firmware_download_finished;
98 }
99
```

***FWUPDATE\_StateTransitionInit*** is called from SSC stack when state changed to INIT. If a download was started before, it has finished now.

***FWUPDATE\_GetDownloadFinished*** is used to check download state inside process\_app. Used to trigger a system reset to start bootloader for updating firmware (copy backup partition to application partition).



# Application – Firmware update example implementation

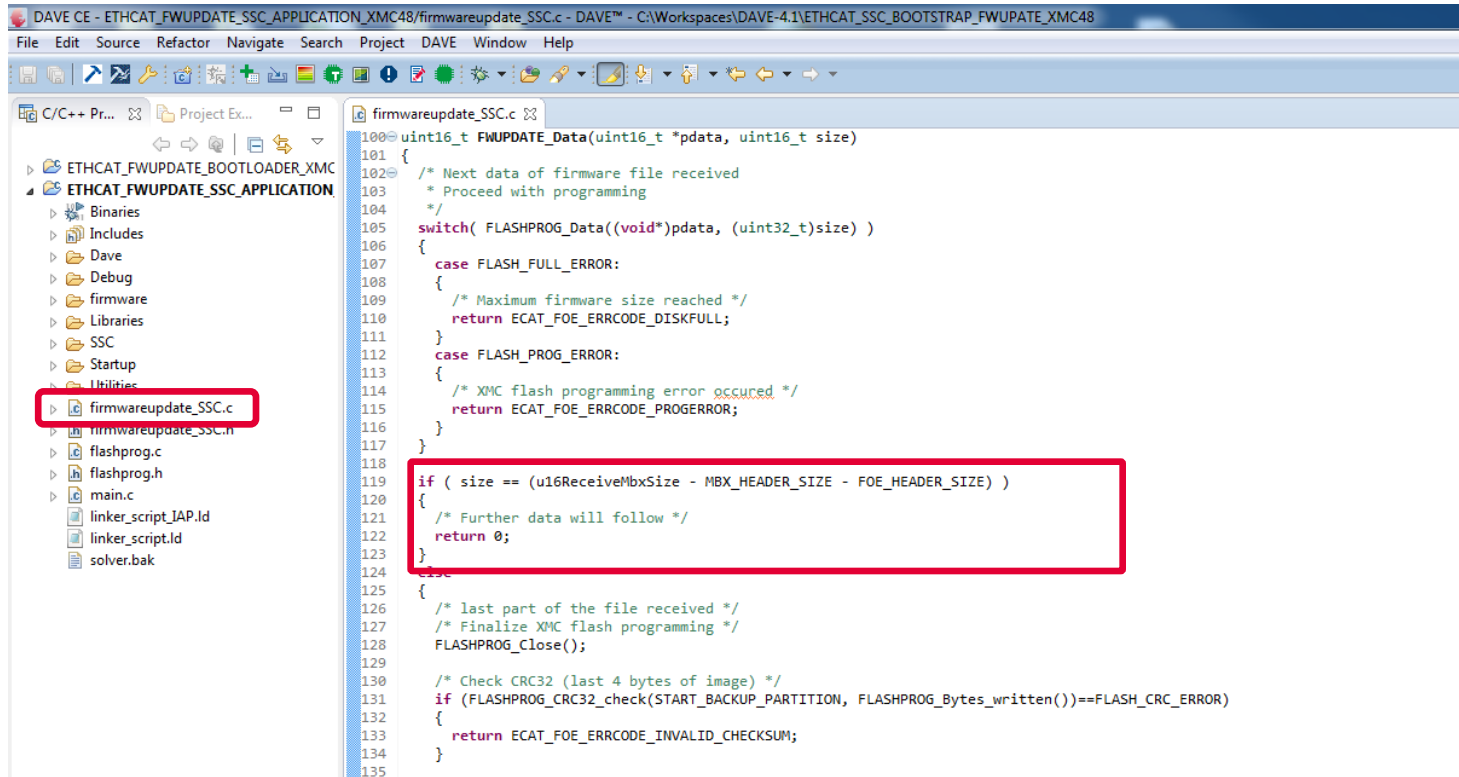


The screenshot displays the Infineon DAVE IDE interface. On the left, the Project Explorer shows the project structure for 'ETHCAT\_FWUPDATE\_SSC\_APPLICATION'. The file 'firmwareupdate\_SSC.c' is highlighted. The main editor window shows the C code for 'firmwareupdate\_SSC.c'. The code defines a function 'FWUPDATE\_Data' that takes a pointer to a 'uint16\_t' array and its size. It uses a switch statement to handle different flash programming errors. A red box highlights the error handling logic, and another red box highlights the function signature and the switch statement.

```
100 uint16_t FWUPDATE_Data(uint16_t *pdata, uint16_t size)
101 {
102     /* Next data of firmware file received
103     * Proceed with programming
104     */
105     switch( FLASHPROG_Data((void*)pdata, (uint32_t)size) )
106     {
107     case FLASH_FULL_ERROR:
108     {
109         /* Maximum firmware size reached */
110         return ECAT_FOE_ERRCODE_DISKFULL;
111     }
112     case FLASH_PROG_ERROR:
113     {
114         /* XMC flash programming error occurred */
115         return ECAT_FOE_ERRCODE_PROGERROR;
116     }
117     }
118
119     if ( size == (u16ReceiveMbxSize - MBX_HEADER_SIZE - FOE_HEADER_SIZE) )
120     {
121         /* Further data will follow */
122         return 0;
123     }
124     else
125     {
126         /* last part of the file received */
127         /* Finalize XMC flash programming */
128         FLASHPROG_Close();
129
130         /* Check CRC32 (last 4 bytes of image) */
131         if (FLASHPROG_CRC32_check(START_BACKUP_PARTITION, FLASHPROG_Bytes_written())==FLASH_CRC_ERROR)
132         {
133             return ECAT_FOE_ERRCODE_INVALID_CHECKSUM;
134         }
135     }
136 }
```

***FWUPDATE\_Data*** is called from SSC stack sequentially for all the file data. Forward data to flash programming. Return error if flash is full or programming error occurred.

# Application – Firmware update example implementation

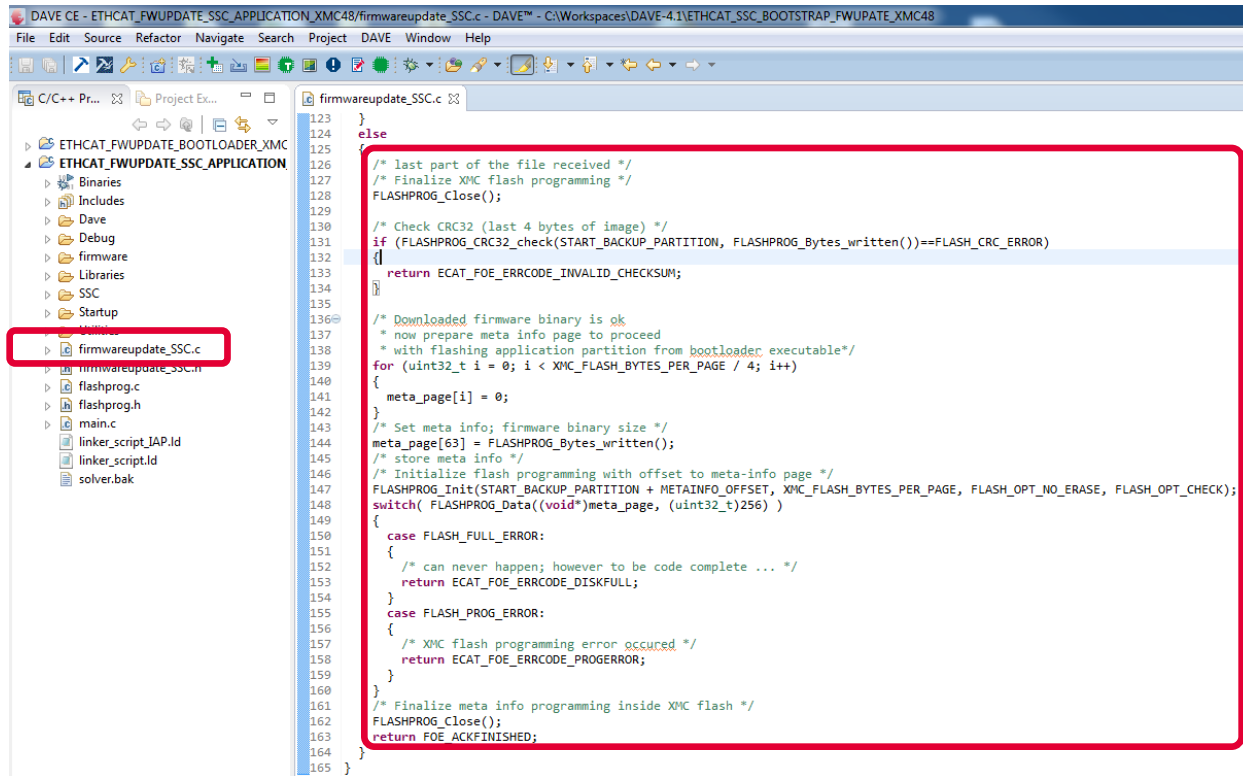


```
100 uint16_t FWUPDATE_Data(uint16_t *pdata, uint16_t size)
101 {
102     /* Next data of firmware file received
103     * Proceed with programming
104     */
105     switch( FLASHPROG_Data((void*)pdata, (uint32_t)size) )
106     {
107     case FLASH_FULL_ERROR:
108     {
109         /* Maximum firmware size reached */
110         return ECAT_FOE_ERRCODE_DISKFULL;
111     }
112     case FLASH_PROG_ERROR:
113     {
114         /* XMC flash programming error occurred */
115         return ECAT_FOE_ERRCODE_PROGERROR;
116     }
117     }
118     if ( size == (u16ReceiveMbxSize - MBX_HEADER_SIZE - FOE_HEADER_SIZE) )
119     {
120         /* Further data will follow */
121         return 0;
122     }
123     else
124     {
125         /* last part of the file received */
126         /* Finalize XMC flash programming */
127         FLASHPROG_Close();
128
129         /* Check CRC32 (last 4 bytes of image) */
130         if (FLASHPROG_CRC32_check(START_BACKUP_PARTITION, FLASHPROG_Bytes_written())==FLASH_CRC_ERROR)
131         {
132             return ECAT_FOE_ERRCODE_INVALID_CHECKSUM;
133         }
134     }
135 }
```

## ***FWUPDATE\_Data (cont'd)***

Use fill status of mailbox to check, if file transfer is complete.  
If file transfer is not complete, return 0 to receive further data.

# Application – Firmware update example implementation

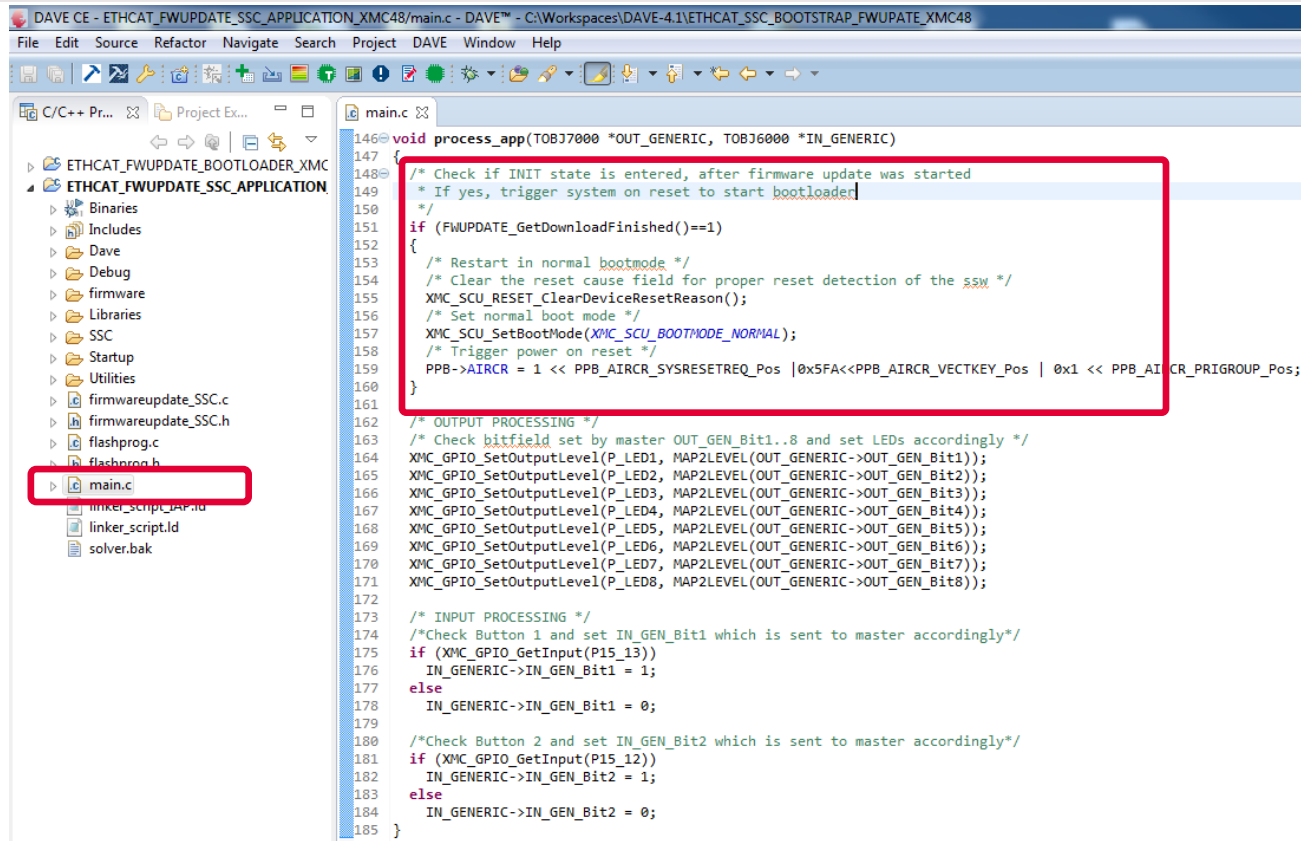


```
123 }
124 else
125 {
126     /* Last part of the file received */
127     /* Finalize XMC flash programming */
128     FLASHPROG_Close();
129
130     /* Check CRC32 (last 4 bytes of image) */
131     if (FLASHPROG_CRC32_check(START_BACKUP_PARTITION, FLASHPROG_Bytes_written())==FLASH_CRC_ERROR)
132     {
133         return ECAT_FOE_ERRCODE_INVALID_CHECKSUM;
134     }
135
136     /* Downloaded firmware binary is ok
137     * now prepare meta info page to proceed
138     * with flashing application partition from bootloader executable*/
139     for (uint32_t i = 0; i < XMC_FLASH_BYTES_PER_PAGE / 4; i++)
140     {
141         meta_page[i] = 0;
142     }
143     /* Set meta info; firmware binary size */
144     meta_page[63] = FLASHPROG_Bytes_written();
145     /* store meta info */
146     /* Initialize flash programming with offset to meta-info page */
147     FLASHPROG_Init(START_BACKUP_PARTITION + METAINFO_OFFSET, XMC_FLASH_BYTES_PER_PAGE, FLASH_OPT_NO_ERASE, FLASH_OPT_CHECK);
148     switch( FLASHPROG_Data((void*)meta_page, (uint32_t)256) )
149     {
150     case FLASH_FULL_ERROR:
151     {
152         /* can never happen; however to be code complete ... */
153         return ECAT_FOE_ERRCODE_DISKFULL;
154     }
155     case FLASH_PROG_ERROR:
156     {
157         /* XMC flash programming error occurred */
158         return ECAT_FOE_ERRCODE_PROGERROR;
159     }
160     }
161     /* Finalize meta info programming inside XMC flash */
162     FLASHPROG_Close();
163     return FOE_ACKFINISHED;
164 }
165 }
```

## ***FWUPDATE\_Data (cont'd)***

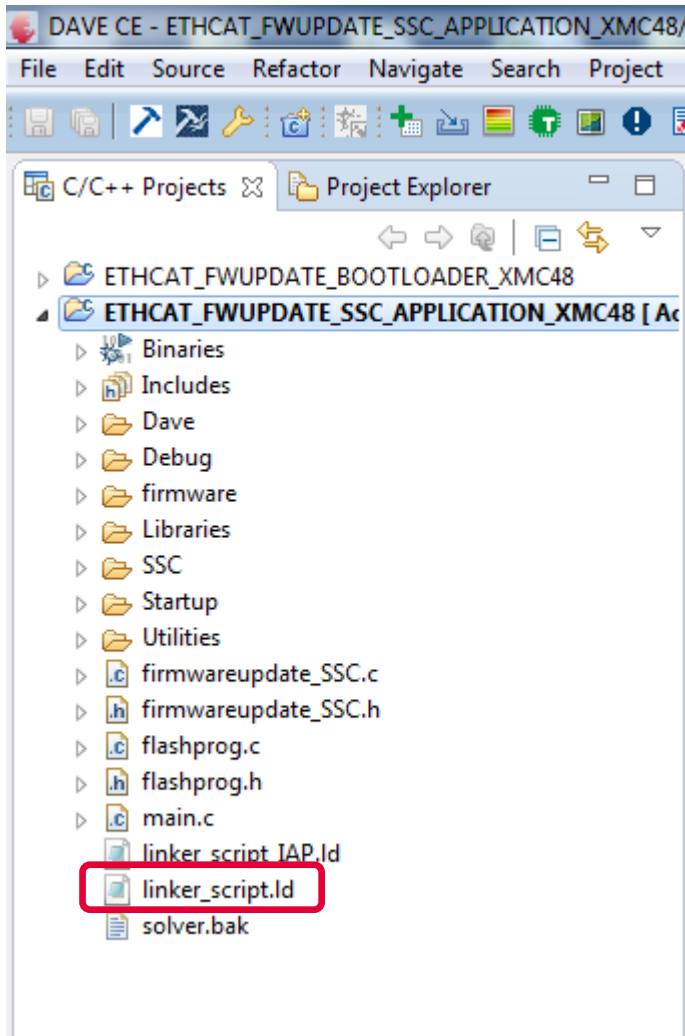
Use fill status of mailbox to check if file transfer is complete. If file transfer is complete, close current programming. Check CRC32 of flash content (last 4 bytes of binary must carry CRC) and return error if needed. Prepare page data (256 byte) for meta info. Write meta info to flash. Return code for successful file transfer FOE\_ACKFINISHED.

# Application – Trigger system reset to restart with bootloader executable



```
146 void process_app(TOB37000 *OUT_GENERIC, TOB36000 *IN_GENERIC)
147 {
148     /* Check if INIT state is entered, after firmware update was started
149     * If yes, trigger system on reset to start bootloader
150     */
151     if (FWUPDATE_GetDownloadFinished()==1)
152     {
153         /* Restart in normal bootmode */
154         /* Clear the reset cause field for proper reset detection of the s5m */
155         XMC_SCU_RESET_ClearDeviceResetReason();
156         /* Set normal boot mode */
157         XMC_SCU_SetBootMode(XMC_SCU_BOOTMODE_NORMAL);
158         /* Trigger power on reset */
159         PPB->AIRCR = 1 << PPB_AIRCR_SYSRESETREQ_Pos | 0x5FA << PPB_AIRCR_VECTKEY_Pos | 0x1 << PPB_AIRCR_PRIGROUP_Pos;
160     }
161
162     /* OUTPUT PROCESSING */
163     /* Check bitfield set by master OUT_GEN_Bit1..8 and set LEDs accordingly */
164     XMC_GPIO_SetOutputLevel(P_LED1, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit1));
165     XMC_GPIO_SetOutputLevel(P_LED2, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit2));
166     XMC_GPIO_SetOutputLevel(P_LED3, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit3));
167     XMC_GPIO_SetOutputLevel(P_LED4, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit4));
168     XMC_GPIO_SetOutputLevel(P_LED5, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit5));
169     XMC_GPIO_SetOutputLevel(P_LED6, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit6));
170     XMC_GPIO_SetOutputLevel(P_LED7, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit7));
171     XMC_GPIO_SetOutputLevel(P_LED8, MAP2LEVEL(OUT_GENERIC->OUT_GEN_Bit8));
172
173     /* INPUT PROCESSING */
174     /* Check Button 1 and set IN_GEN_Bit1 which is sent to master accordingly */
175     if (XMC_GPIO_GetInput(P15_13))
176     {
177         IN_GENERIC->IN_GEN_Bit1 = 1;
178     }
179     else
180     {
181         IN_GENERIC->IN_GEN_Bit1 = 0;
182     }
183
184     /* Check Button 2 and set IN_GEN_Bit2 which is sent to master accordingly */
185     if (XMC_GPIO_GetInput(P15_12))
186     {
187         IN_GENERIC->IN_GEN_Bit2 = 1;
188     }
189     else
190     {
191         IN_GENERIC->IN_GEN_Bit2 = 0;
192     }
193 }
```

***process\_app*** is cyclic called from SSC stack to implement the application specific behaviour (e.g. I/Os). For the firmware update example here it is checked, if backup partition was modified and INIT state entered. If yes, trigger system reset to start bootloader for programming new firmware and/or cleanup backup partition.



Inside the linker file the start address of your application is defined.

The default linker file of DAVE projects defines the location of the vector table and program/data to the flash start address:

0x0C000000

To reserve space for EEPROM emulation the ECAT\_SSC APP used inside your project, overwrites this default linker file with every code generation to remap the program/data start address:

0x0C000000 vector table

0x0C020000 program/data

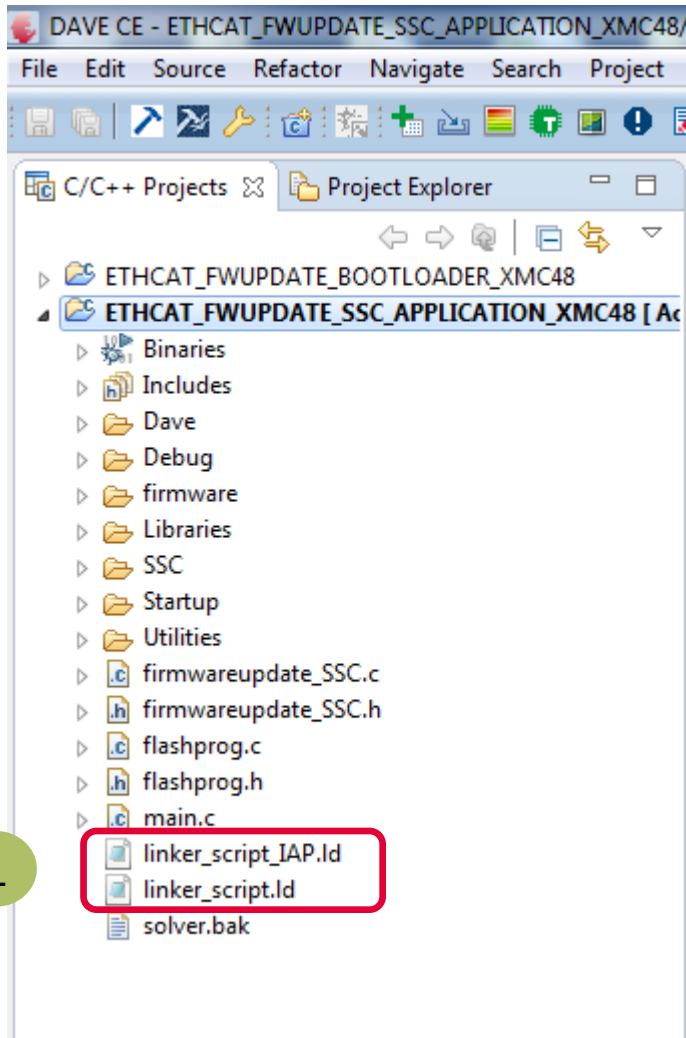
This setting does not match to flash partitioning used for this example, because the vector table overlaps with the bootloader partition.

Instead, the following setting is needed:

0x0C020000 vector table + program/data

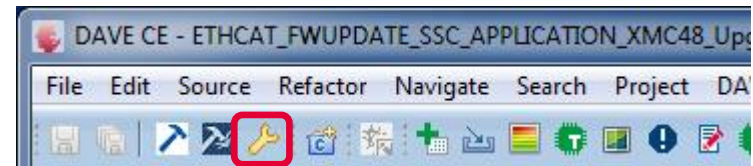
→ **The linker file must be modified and overwriting with every APP code generation must be avoided.**

**See the following slides to do this**

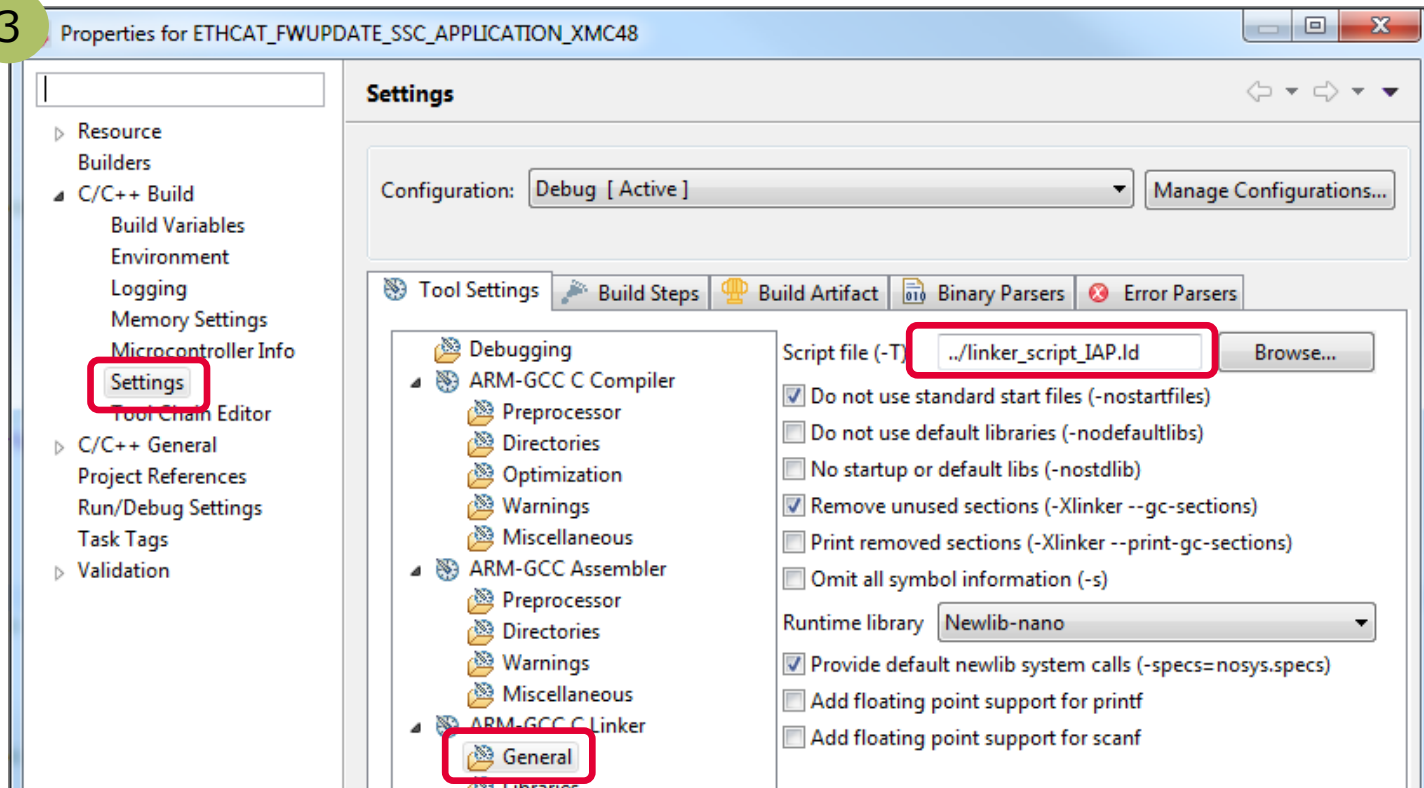


To avoid regular overwriting of the linker file by code generation of the ECAT\_SSC APP, follow these steps:

- 1 Create a copy of the linker file and rename the copy:  
„linker\_script\_IAP.ld“
- 2 Open project properties:



3



3

Define name of linker file: „linker\_script\_IAP.ld“



# Application – Modifying the linker file

```
linker_script_IAP.ld  linker_script.ld
63 MEMORY
64 {
65   FLASH_0_cached(RX) : ORIGIN = 0x08000000, LENGTH = 0x00010000
66   FLASH_0_uncached(RX) : ORIGIN = 0x0C000000, LENGTH = 0x00010000
67   FLASH_1_cached(RX) : ORIGIN = 0x08020000, LENGTH = 0x001E0000
68   FLASH_1_uncached(RX) : ORIGIN = 0x0C020000, LENGTH = 0x001E0000
69   PSRAM_1(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x18000
70   DSRAM_1_system(!RX) : ORIGIN = 0x20000000, LENGTH = 0x20000
71   DSRAM_2_comm(!RX) : ORIGIN = 0x20020000, LENGTH = 0x20000
72   SRAM_combined(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x00058000
73 }
74
75 SECTIONS
76 {
77   /* TEXT section */
78
79   .reset :
80   {
81     KEEP(*(.reset));
82     > FLASH_0_cached AT > FLASH_0_uncached
83   }
84   .text :
85   {
86     sText = .;
87     *(.text .text.* .gnu.linkonce.t.*);
88
89     /* C++ Support */
90     KEEP(*(.init))
91     KEEP(*(.fini))
92
93     /* ctors */
94   }
```



4

```
linker_script_IAP.ld  linker_script.ld
63 MEMORY
64 {
65   FLASH_0_cached(RX) : ORIGIN = 0x08000000, LENGTH = 0x00010000
66   FLASH_0_uncached(RX) : ORIGIN = 0x0C000000, LENGTH = 0x00010000
67   FLASH_1_cached(RX) : ORIGIN = 0x08020000, LENGTH = 0x001E0000
68   FLASH_1_uncached(RX) : ORIGIN = 0x0C020000, LENGTH = 0x001E0000
69   PSRAM_1(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x18000
70   DSRAM_1_system(!RX) : ORIGIN = 0x20000000, LENGTH = 0x20000
71   DSRAM_2_comm(!RX) : ORIGIN = 0x20020000, LENGTH = 0x20000
72   SRAM_combined(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x00058000
73 }
74
75 SECTIONS
76 {
77   /* TEXT section */
78
79   .text : ALIGN (4)
80   {
81     sText = .;
82     KEEP(*(.reset));
83     *(.text .text.* .gnu.linkonce.t.*);
84
85     /* C++ Support */
86     KEEP(*(.init))
87     KEEP(*(.fini))
88
89     /* .ctors */
90     *crtbegin.o(.ctors)
91     *crtbegin?.o(.ctors)
92     /* ... other ctors ... */
93   }
```

4 Modify the new linker file. Move assignment of vector table to text section inside „linker\_script\_IAP.ld“



# Application – Creating the binary output including CRC32

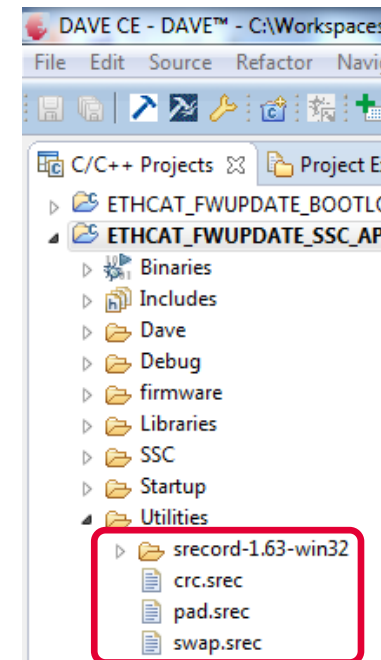
The firmware update files used inside this example have the following format:

1. Binary output format
2. The size of binary data must be a multiple of 4 bytes (word aligned)
3. The last word should represent the CRC32 of the previous binary data

→ SRecord is used to automate the formatting of the binary output.

The windows executable of SRecord and prepared scripts are provided inside the example to get the job done.

See the following slides how the tool is integrated into the output linking stage of DAVE™.

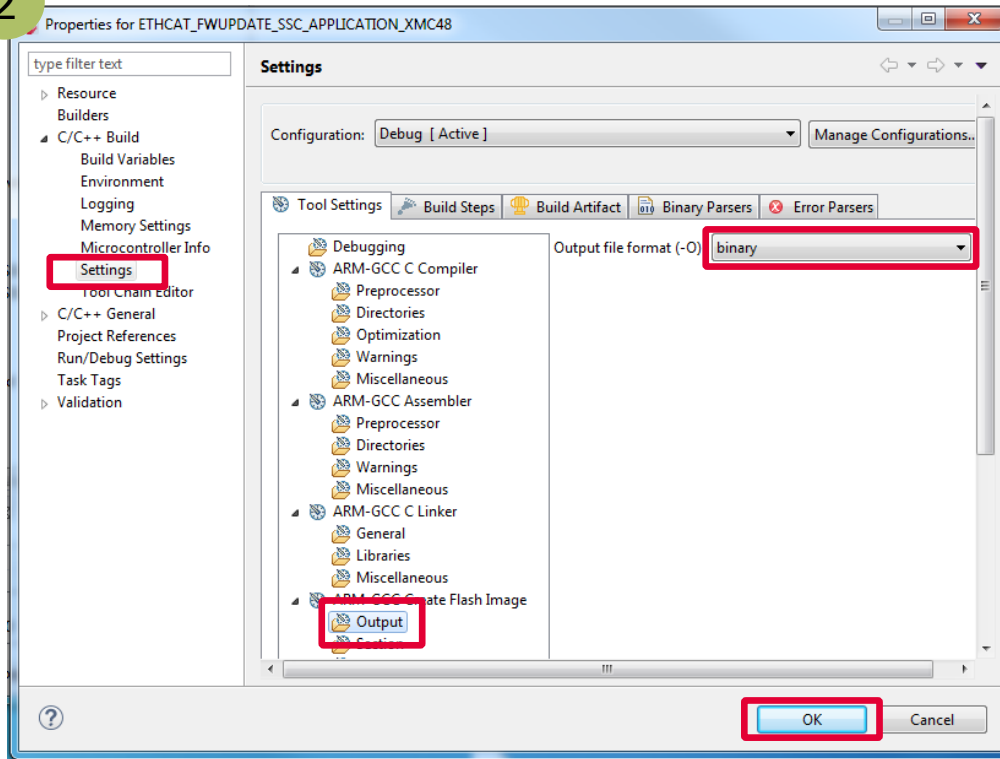


# Application – Creating the binary output including CRC32

1



2

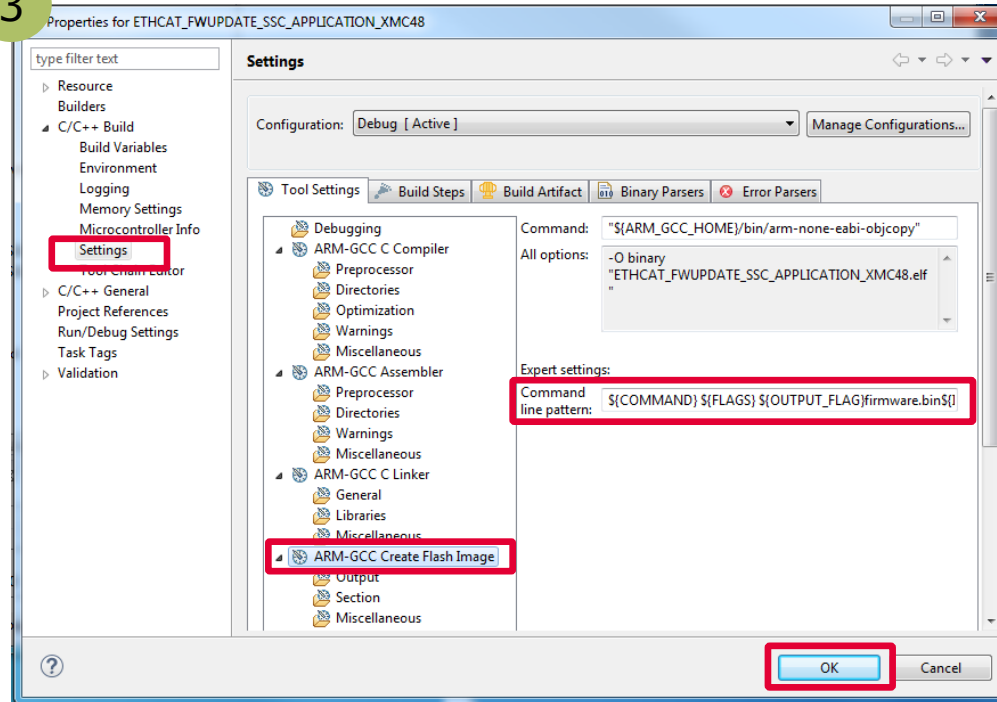


1 Open project properties dialog

2 Set output format to binary format

# Application – Creating the binary output including CRC32

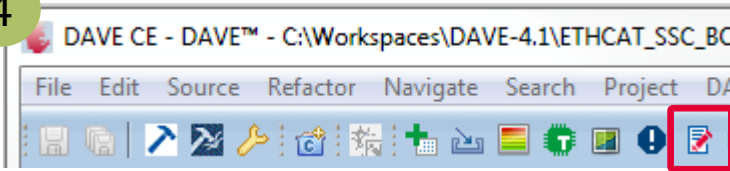
3



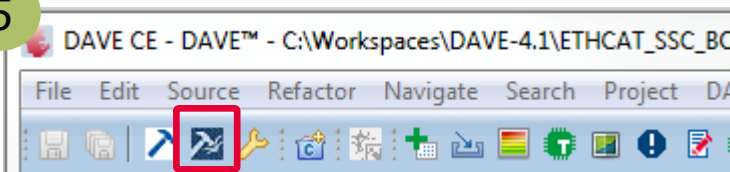
3 Modify the command line pattern for post processing:  
`${COMMAND} ${FLAGS} ${OUTPUT_FLAG}firmware.bin${INPUTS} & ..../Utilities/srecord-1.63-win32/srec_cat \"@../Utilities/pad.srec\" & ..../Utilities/srecord-1.63-win32/srec_cat \"@../Utilities/crc.srec\" & ..../Utilities/srecord-1.63-win32/srec_cat \"@../Utilities/swap.srec\"`

# Application – Creating the binary output including CRC32

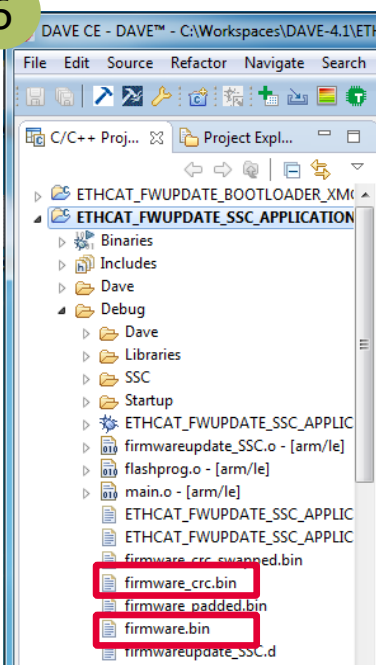
4



5



6



4

Regenerate the source code for DAVE™ APPs

5

Rebuild the project

6

Find the result inside debug folder:

*firmware.bin*

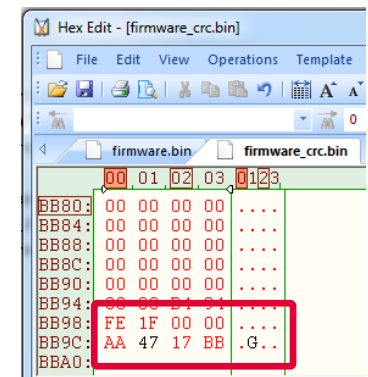
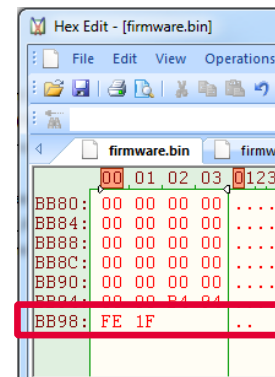
- binary output unmodified

*firmware\_CRC.bin*

- binary output padded to word alignment

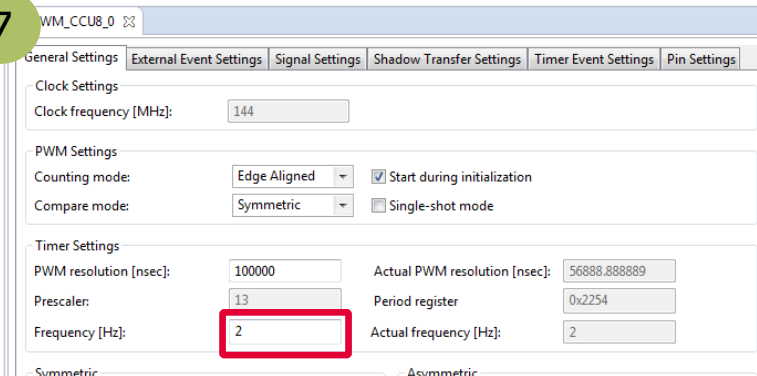
- CRC32 added.

Use a hex editor to visualize the diff:

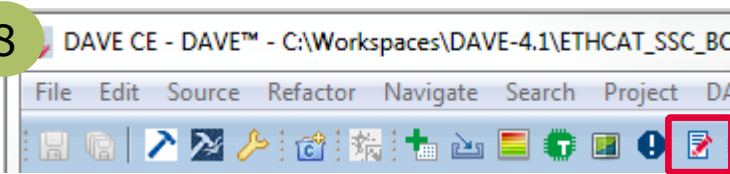


# Application – Creating the binary output including CRC32 for testing

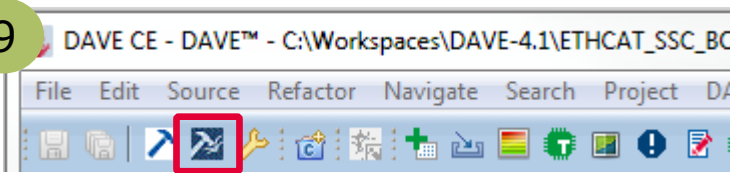
7



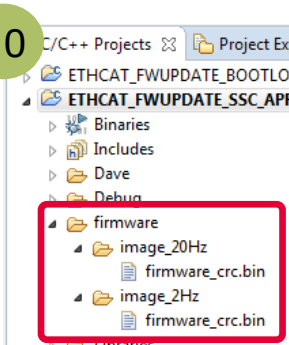
8



9



10



Inside the test section of this documentation two firmware update binaries are needed:

- LED2 flashing with 2Hz
- LED2 flashing with 20Hz

To prepare the two binaries set the flash frequency inside PWM\_CCUC8 APP to 20Hz/2Hz and create the binaries:

- 7 Set frequency
- 8 Generate source code for APPs
- 9 Rebuild the project
- 10 For your convenience the two firmware update binaries are already prepared and are delivered within the project.

- 1 Overview and requirements
- 2 Setup
- 3 Short overview – boot modes
- 4 Architecture
- 5 Implementation of the application
- 6 **Implementation of the bootloader**
- 7 How to test – using TwinCAT3 as host

# Bootloader – implementing main()

```
main.c
140 ~
141 uint32_t main(void)
142 {
143     uint32_t firmware_size_bytes;
144     uint32_t * ptr_backupdata = 0;
145     firmware_size_bytes = (START_ADDRESS_BACKUP_PARTITION + METAINFO_OFFSET / 4)[63];
146
147     /* check metainfo if firmware for update is available inside backup partition */
148     if ( (firmware_size_bytes > 0) && (firmware_size_bytes < APP_PARTITION_MAX_SIZE) )
149     {
150         /* metainfo indicates a new firmware is available inside backup partition */
151         /* check CRC32 of firmware inside backup partition */
152         if (FLASHPROG_CRC32_check(START_ADDRESS_BACKUP_PARTITION,
153                                 firmware_size_bytes) == FLASH_OK)
154         {
155             /* CRC32 of backup partition is OK - start programming */
156
157             /* program new firmware into application partition */
158             FLASHPROG_Init(START_ADDRESS_APP_PARTITION,
159                           APP_PARTITION_MAX_SIZE,
160                           FLASH_OPT_ERASE,
161                           FLASH_OPT_CHECK);
162             FLASHPROG_Data(START_ADDRESS_BACKUP_PARTITION, firmware_size_bytes);
163             FLASHPROG_Close();
164
165             /* delete EEPROM content (2nd 64k sector) */
166             FLASHPROG_Delete_physical_sector(XMC_FLASH_PHY_SECTOR_4);
167
168             /* Check CRC32 of firmware inside application partition */
169             if (FLASHPROG_CRC32_check(START_ADDRESS_APP_PARTITION,
170                                     firmware_size_bytes) != FLASH_OK)
171             {
172                 /* Restart to retry programming */
173                 BL_Normal_Restart();
174             }
175             /* OK - new firmware was successfully programmed into application partition */
176         }
177     }
178
179     /* CRC32 checked software from backup partition was just successfully programmed
180     * into application partition.
181     * In any case, make sure backup partition is erased before restarting firmware inside
182     * application partition.
183     */
184     ptr_backupdata = START_ADDRESS_BACKUP_PARTITION;
185     while(ptr_backupdata < START_ADDRESS_BACKUP_PARTITION + BACKUP_PARTITION_MAX_SIZE / 4)
186     {
187         /* is erase needed? */
188         if (*ptr_backupdata != 0)
189         {
190             /* erase backup partition */
191             FLASHPROG_Delete_physical_sectors(ptr_backupdata, 1);
192         }
193         ptr_backupdata++;
194     }
195
196     /* Restart inside application partition */
197     BL_FlashABM0_Restart();
198
199     return 0;
200 }
```

- 1 Check meta info if new firmware binary is available inside backup partition
- 2 If CRC32 check of backup partition is OK, start programming new software.  
Delete EEPROM content of old firmware. If CRC32 check of new programmed application partition is not OK (which is most unlikely to happen) restart bootloader to retry.
- 3 Check if backup partition is polluted for any reason. If yes, clean it before starting application executable. By this, backup partition is always clean when application executable is started.
- 4 Restart device with application executable.

# Bootloader – triggering restart in alternative boot mode 0 and normal boot mode

```
main.c
109
110 /* *****
111  * API IMPLEMENTATION
112  * *****
113  */
114 void BL_FlashABM0_Restart(void)
115 {
116     /* Restart in alternative bootmode 0 */
117     /* Clear the reset cause field for proper reset detection of the ssw */
118     XMC_SCU_RESET_ClearDeviceResetReason();
119     /* Set ABM0 as boot mode in SWCON field of STCON register */
120     XMC_SCU_SetBootMode(XMC_SCU_BOOTMODE_ABM0);
121     /* Trigger power on reset */
122     PPB->AIRC = 1 << PPB_AIRC_SYSRESETREQ_Pos
123                   | 0x5FA << PPB_AIRC_VECTKEY_Pos
124                   | 0x1 << PPB_AIRC_PRIGROUP_Pos;
125 }
126
127 void BL_Normal_Restart(void)
128 {
129     /* Restart in alternative bootmode 0 */
130     /* Clear the reset cause field for proper reset detection of the ssw */
131     XMC_SCU_RESET_ClearDeviceResetReason();
132     /* Set ABM0 as boot mode in SWCON field of STCON register */
133     XMC_SCU_SetBootMode(XMC_SCU_BOOTMODE_NORMAL);
134     /* Trigger power on reset */
135     PPB->AIRC = 1 << PPB_AIRC_SYSRESETREQ_Pos
136                   | 0x5FA << PPB_AIRC_VECTKEY_Pos
137                   | 0x1 << PPB_AIRC_PRIGROUP_Pos;
138 }
```

- 1 To restart in alternative boot mode 0, the following actions are needed:

Clear the reset source of the last reset

Set boot mode to alternative boot mode

Issue system reset (software reset)

- 2 To restart in normal boot mode, the following actions are needed:

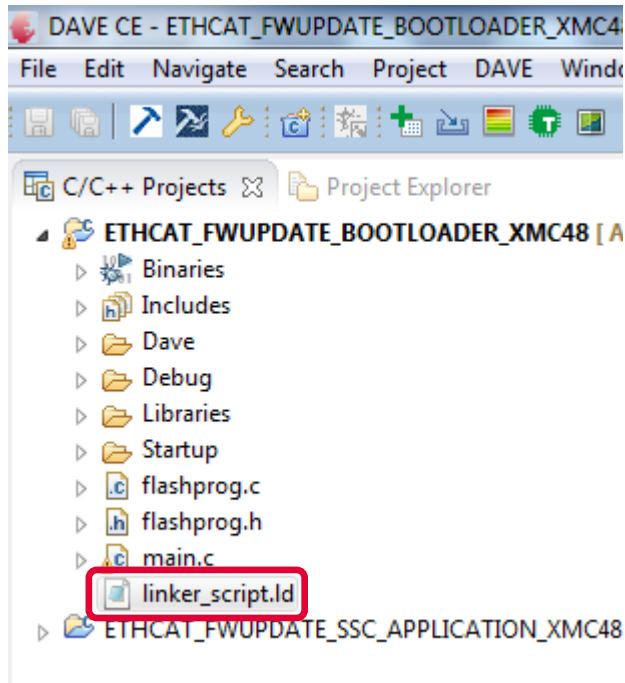
Clear the reset source of the last reset

Set boot mode to normal boot mode

Issue system reset (software reset)

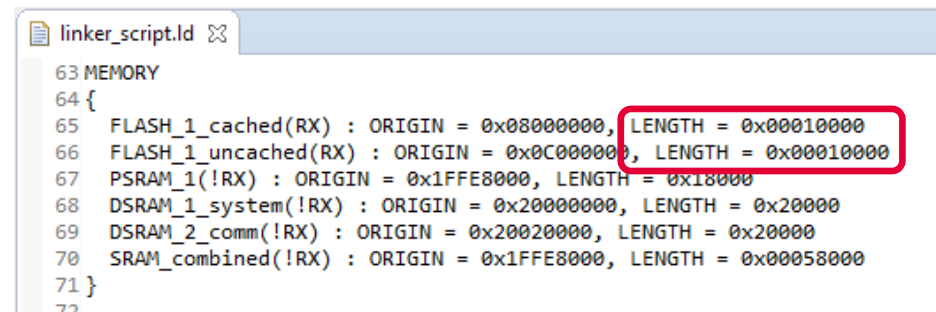


# Bootloader – Limit bootloader flash size inside linker file



The bootloader executable is limited to the first 64KB inside flash.

To make build aware of this limitation, the linker file has to be adapted:



```
63 MEMORY
64 {
65   FLASH_1_cached(RX) : ORIGIN = 0x08000000, LENGTH = 0x00010000
66   FLASH_1_uncached(RX) : ORIGIN = 0x0C000000, LENGTH = 0x00010000
67   PSRAM_1(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x18000
68   DSRAM_1_system(!RX) : ORIGIN = 0x20000000, LENGTH = 0x20000
69   DSRAM_2_comm(!RX) : ORIGIN = 0x20020000, LENGTH = 0x20000
70   SRAM_combined(!RX) : ORIGIN = 0x1FFE8000, LENGTH = 0x00058000
71 }
72
```

```
main.c
47 //*****
48 * MACROS AND DEFINES
49 //*****
50 /** MagicKey value for \ref ABM_Header_t. see */
51 #define ABM_HEADER_MAGIC_KEY 0xA5C3E10F
52 //*****
53 #define START_ADDRESS_BACKUP_PARTITION (uint32_t*)0x0C100000
54 /* start address of application buffer
55 * (@128kByte after bootloader(64k) and EEPROM(64k)*/
56 #define START_ADDRESS_APP_PARTITION (uint32_t*)0x0C200000
57 /* first 128KByte is occupied by bootloader */
58 #define APP_PARTITION_MAX_SIZE (1024 * 1024 - 128 * 1024)
59 /* backup space including meta-info space */
60 #define BACKUP_PARTITION_MAX_SIZE (1024 * 1024)
61 /* offset to backup start address
62 * of page to store file size inside backup */
63 #define METAINFO_OFFSET (1024 * 1024 - 256)
64 //*****
65 /* \brief Alternative Boot Mode structure
66 */
67 typedef struct ABM_Header {
68     uint32_t MagicKey; /**< Magic key. Always 0xA5C3E10F */
69     uint32_t StartAddress; /**< Start address of the program to load */
70     uint32_t Length; /**< Length of the program to load. */
71     uint32_t ApplicationCRC32; /**< CRC32 Sum of the complete application code */
72     uint32_t HeaderCRC32; /**< CRC32 Sum of the four fields before */
73 } ABM_Header_t;
74 //*****
75 * LOCAL DATA
76 //*****
77 static const ABM_Header_t __attribute__((section(".flash_abm")))
78 ABM0_Header = {
79     .MagicKey = ABM_HEADER_MAGIC_KEY,
80     .StartAddress = 0x08020000, /* Start Flash Physical Sector 1 */
81     .Length = 0xFFFFFFFF,
82     .ApplicationCRC32 = 0xFFFFFFFF,
83     .HeaderCRC32 = 0xEF423163
84 };
85 //*****
86 * API PROTOTYPES
87 //*****
88
89
```

```
linker script.ld
131 /* http://mcuoneclipse.com/2012/11/01/defining-variables-
132 .abm ABSOLUTE(0x0800FFE0): AT(0x0800FFE0 | 0x04000000)
133 {
134     KEEP(*(.flash_abm))
135 } > FLASH_1_cached
136
137 /* DSRAM layout (Lowest to highest)*/
138 Stack (NOLOAD) :
139 {

```

Inside bootloader partition the ABM0 header must be located:

- 1 Define magic key of ABM header
- 2 Define ABM header structure
- 3 Define content of ABM header and location inside flash. Beside magic key and CRC, the start address of the flash is the only mandatory information needed.
- 4 Define location of ABM header inside linker script to the last 32byte inside the first 64KB of flash:  
0x0C00FFE0

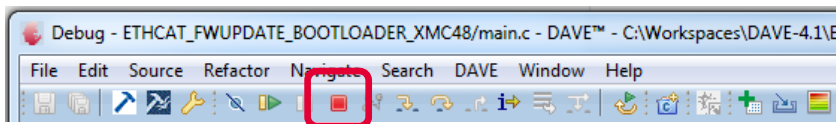
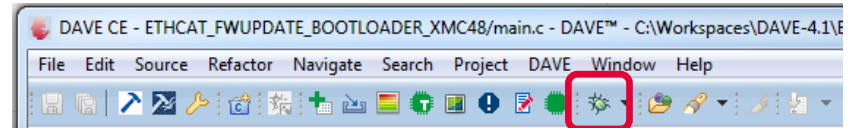
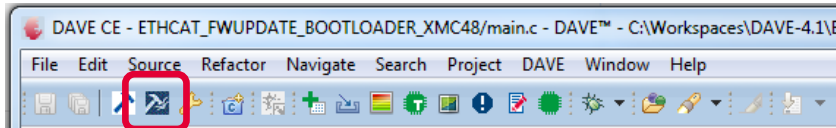
- 1 Overview and requirements
- 2 Setup
- 3 Short overview – boot modes
- 4 Architecture
- 5 Implementation of the application
- 6 Implementation of the bootloader
- 7 How to test – using TwinCAT3 as host

# How to test – Downloading the executables and start application executable via bootloader

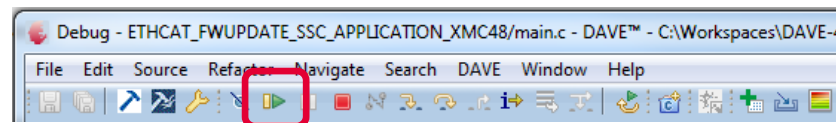
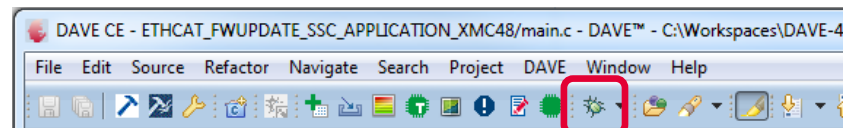
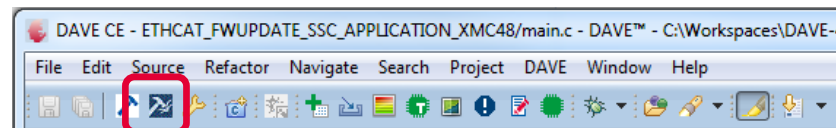


## ACTIONS

1. Set bootloader as active project, build and download the bootloader executable software to the XMC4800 and stop debugger



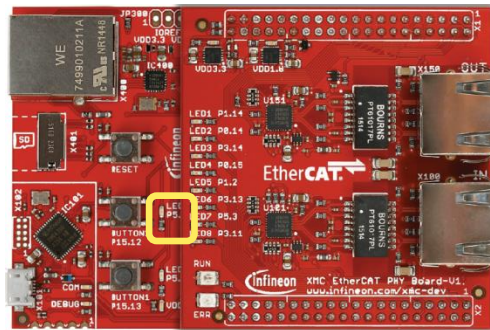
2. Set application as active project, build and download the application executable software to the XMC4800 and start the debugger



Note: Please be aware the application executable has reached the breakpoint inside main() already via bootloader executable

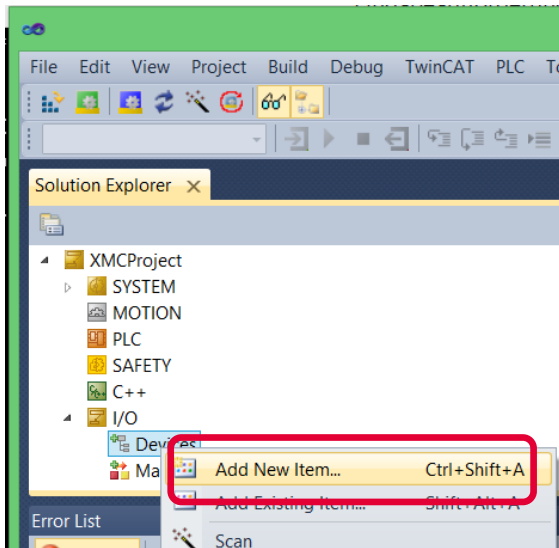


Check LED2 is flashing with a rate of 2Hz

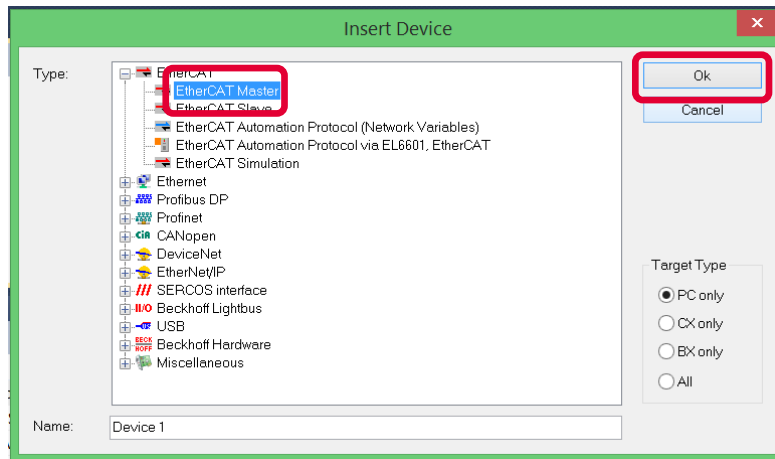


# How to test – start the TwinCAT 3 master to run (1/4)

1



2



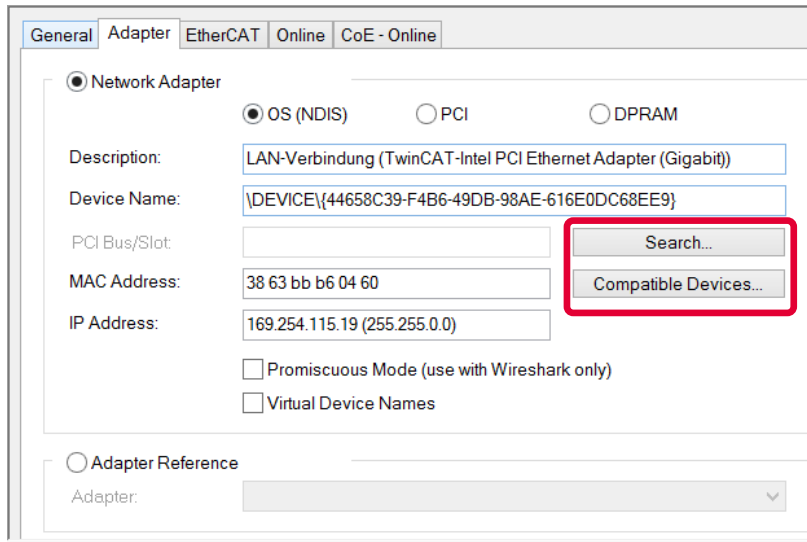
## ACTIONS

After starting the TwinCAT System Manager from windows start menu:

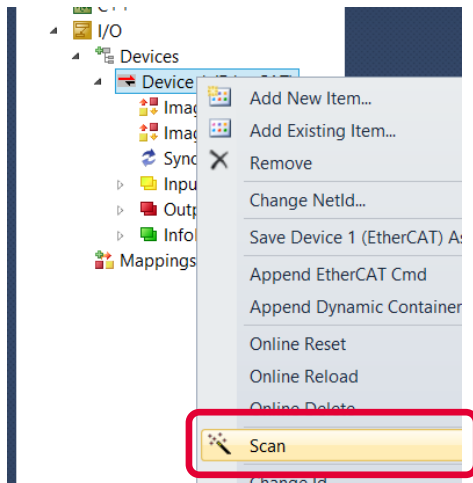
- 1 Right Click I/O-Devices and select „Add New Item...”
- 2 Create an EtherCAT master device by double click

# How to test – start the TwinCAT 3 master to run (2/4)

3



4



## ACTIONS

- 3 Select the network adapter you want to use (search and select).

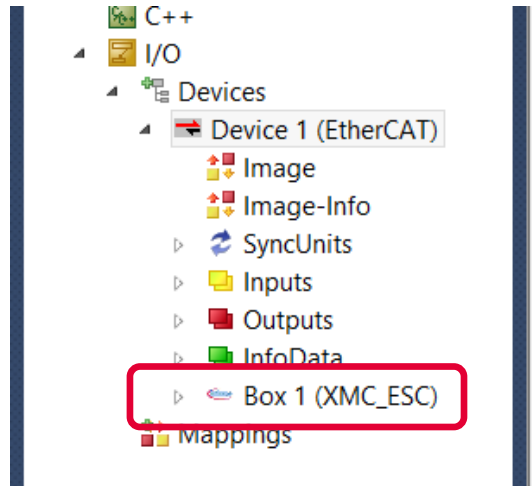
Application hint:

In case the device is not found please install the respective device driver by following the instructions given by TwinCAT through the „Compatible Devices...” button.

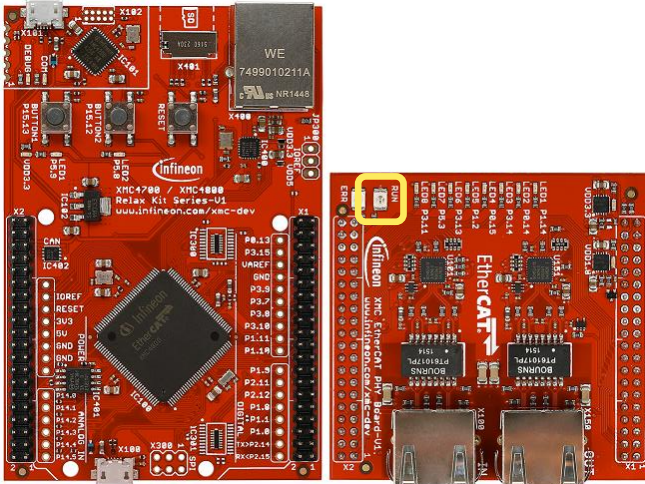
- 4 Right Click EtherCAT master and select „Scan Boxes...”

# How to test – start the TwinCAT 3 master to run (3/4)

1



2



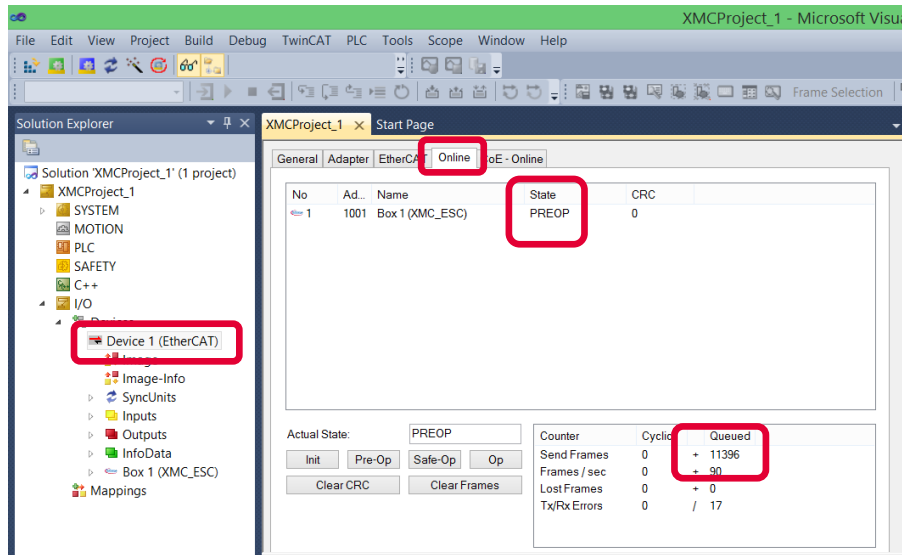
## OBSERVATIONS

- 1 The slave appears as a node on the EtherCAT master bus
- 2 The RUN-LED is flashing indicating PREOP-state

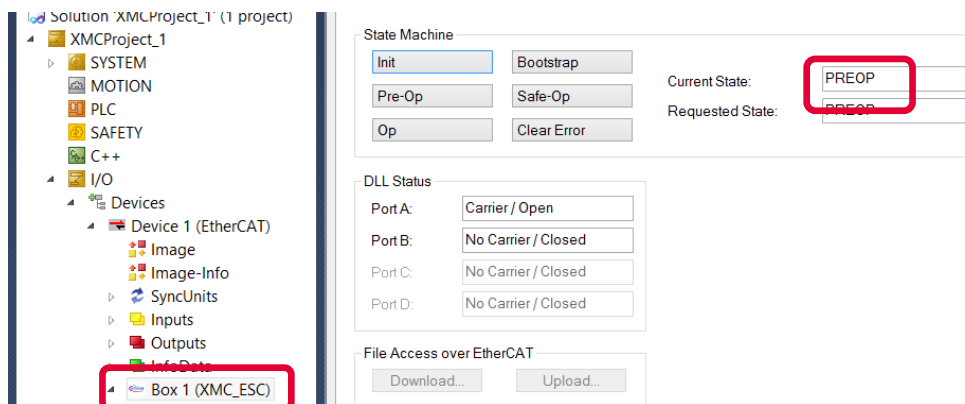


# How to test – start the TwinCAT 3 master to run (4/4)

3



4



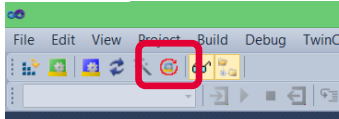
## OBSERVATIONS

- 3 EtherCAT master view:  
Inside the EtherCAT master online state you see the queued frames counting up, the connected slave and its PREOP state.
- 4 EtherCAT slave view:  
The PREOP-state of the slave is indicated within the TwinCAT system manager .

# How to test – Setting slave to operational mode



## ACTION

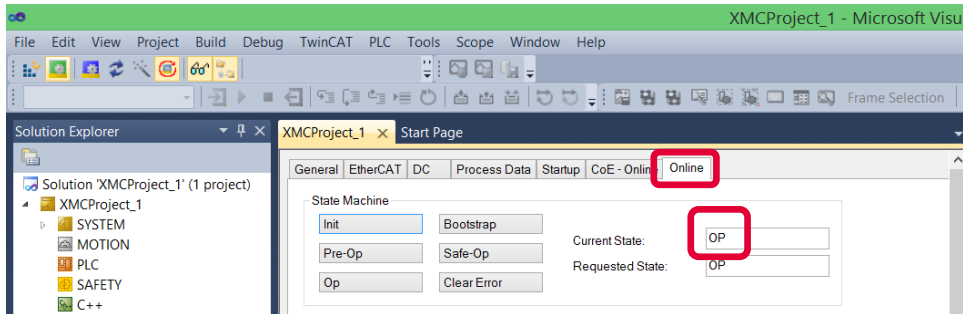


Set master device to free run mode



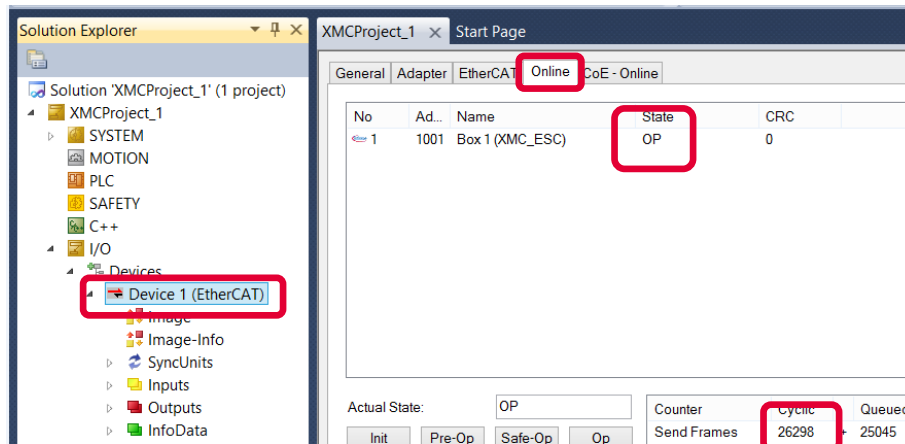
## OBSERVATIONS

1



1 EtherCAT slave view:  
Online status of slave shows the slave in OP state

2



2 EtherCAT master view:  
Online status of master shows the slave in OP state. Frames are no more queued. Cyclic counter is incrementing.

3 „XMC EtherCAT PHY Board“:  
RUN-LED is static turned on indicating OP-state.

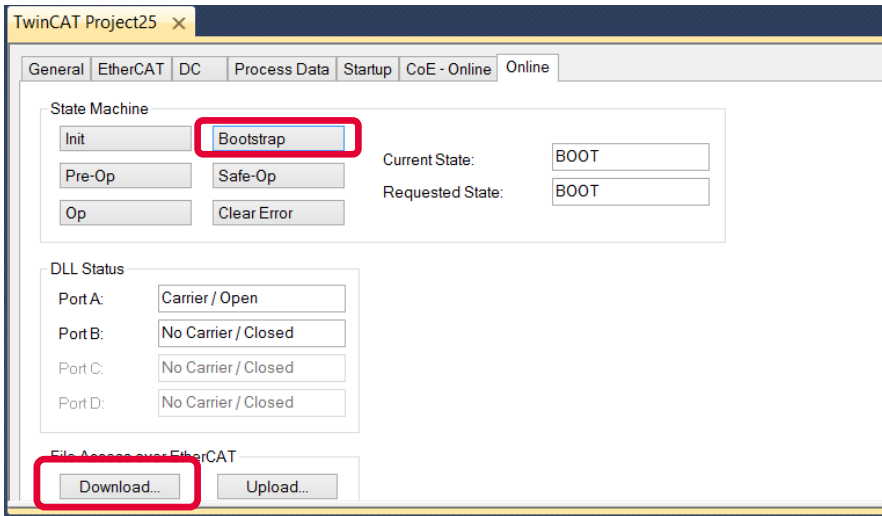
# How to test – Update firmware via FoE



## ACTIONS

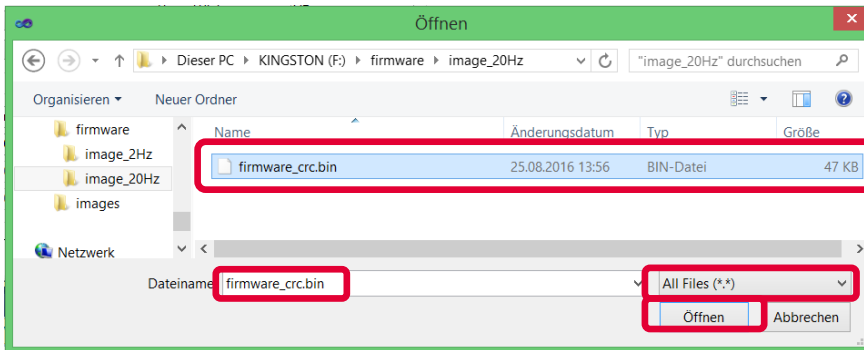
- 1 Enter bootstrap state
- 2 Start download dialog
- 3 Select 20Hz firmware binary
- 4 Enter 32bit passkey „beefbeef“ and confirm with „OK“

1

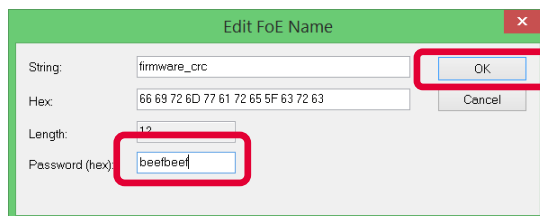


2

3



4

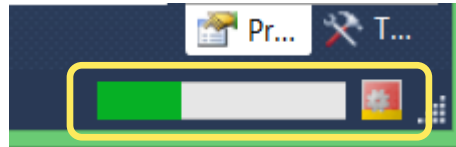


# How to test – Check the progress of firmware download via FoE



## OBSERVATIONS

While the firmware is downloaded to the backup partition, a progress bar in the very right corner of the TwinCAT window indicates the upload status to you.

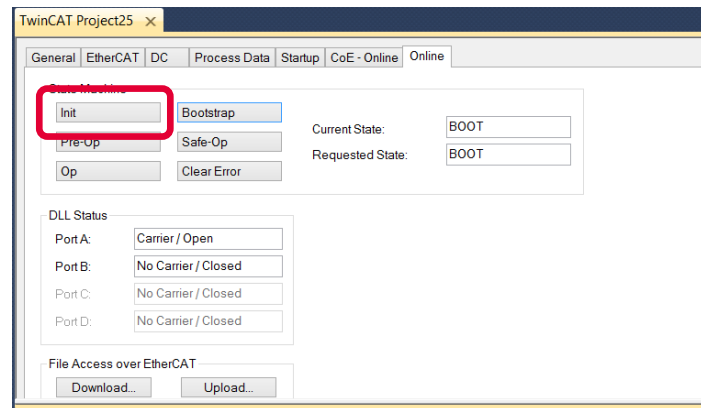


# How to test – Update firmware via FoE



## ACTIONS

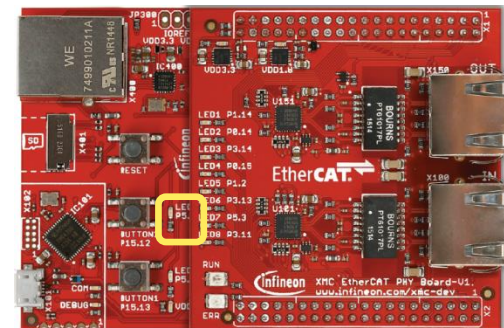
Set slave to INIT state. This triggers the restart of the device with bootloader executable. Firmware inside application partition will be updated.



## OBSERVATIONS

The slave is restarted and after firmware was updated inside flash becomes operational again. Now LED2 is flashing with a rate of 20Hz.

→ Firmware update succeeded





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