

Freescal MQX™ RTOS BSP Porting Example User Guide

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1 Introduction

This document uses a specific example with detailed steps for porting a BSP to a different board and follows the porting process outlined in the *Freescale MQX RTOS BSP Porting Guide* (document MQXBSPPG).

2 Example

First, TWR-K60D100M BSP is ported to a different development board TWR-K40D100M. While MQX already includes a BSP for the TWR-K40D100M board, this guide provides the detailed steps for that BSP port. The example ports to a different Freescale Kinetis MCU derivative: from a 100 MHz K60 to a 100M Hz K40. While these derivatives are similar, there are several differences between the derivatives and the boards which require the following changes in the ported BSP:

- Different Peripherals
 - K60 includes an Ethernet MAC peripheral, the K40 does not
 - The K40 has a Segment LCD peripheral, the K60 does not
- Different memory map and sizes
 - The K60 has 512 KB of Program Flash, this K40 has 256 KB
 - The K60 has 128 KB of system SRAM, this K40 has 64 KB
 - The K40 includes FlexMemory with 256 KB of FlexNVM, this K60 has no FlexMemory
- Different drivers and driver configurations
 - Different UART peripherals are used for the RS-232 communication of the board
 - Low-power settings for UARTs with LPM driver are different because the different UARTs are used
- Different pins
 - GPIO pins used for:
 - LEDs
 - Input switches
 - USB regulator enable
 - Accelerometer IRQ
 - SD Card socket
 - UART Tx and Rx, and hardware flow control pins
 - I2C pins
 - SAI (I2S)
 - FlexBus
- Different clock setup
 - The clock source on the K60 board is a 50 MHz external oscillator, the K40 board uses a 8 MHz crystal
 - The K60 BSP uses a PLL output of 96 MHz, the customized K40 BSP uses a PLL output of 48 MHz to show implications of this change including the USB clock divider

In this porting example, the name of the customized ported BSP is **CustomBSP**. The example was done with Freescale MQX v4.0.2, using the tool chain releases specified in the MQX Release Notes for CodeWarrior for Microcontrollers, IAR Embedded Workbench® for ARM®, and MDK-ARM Keil™.

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In the porting example, only the Debug build configurations are modified and tested. The Release build configurations can be modified with the same porting steps. The example software MQXPORTESW.zip is available at freescale.com.

3 Cloning the BSP

For the Kinetis derivative MK40DX256VMD10, this example starts with the TWR-K60D100M MQX BSP provided in the MQX release. Cloning is done with the BSP Cloning Wizard. The name for the new clone is **CustomBSP** and the board base to clone is TWR-K60D100M. These steps modify **CustomBSP** to port it to the TWR-K40D100M board.

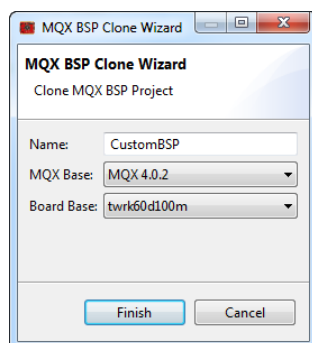


Figure 1: BSP Cloning Wizard Settings

4 Using Processor Expert (PEX) in the BSP

Using PEX in the MQX BSP is optional. This section explains how to add PEX into a BSP project for IAR or Keil. The CodeWarrior projects for the Kinetis MQX BSPs already include PEX support. The projects are released with the PEX components included, but the PEX source code is not generated. Building the projects as released does not use PEX. However, the PEX code can be easily generated within the project and no user integration is required to include PEX in the BSP. Skip to Section [Changing the PEX Package](#) to use PEX in a CodeWarrior BSP project.

4.1 Setting up BSP for PEX with IAR EW-ARM

Since MQX version 4.0.2, the BSP project did not include PEX support. These steps show how to use the PEX Driver Suite and add PEX support to the BSP.

4.1.1 Adding PEX Driver Suite Project

1. In PEX, create a new PEX project using the menu **File->New->Processor Expert Project**
2. Name the project the same name as the BSP project, in this case **bsp_CustomBSP**
3. Do not use the default location. Instead, create the project in the BSP project directory for IAR, in this case **\\mqx\\build\\iar\\bsp_CustomBSP**. Note that the tool defaults to creating a subdirectory under **bsp_CustomBSP** with the same name. Be sure to correct the path so that the PEX project is created in the same directory as the IAR project. The warning caused by this is OK.

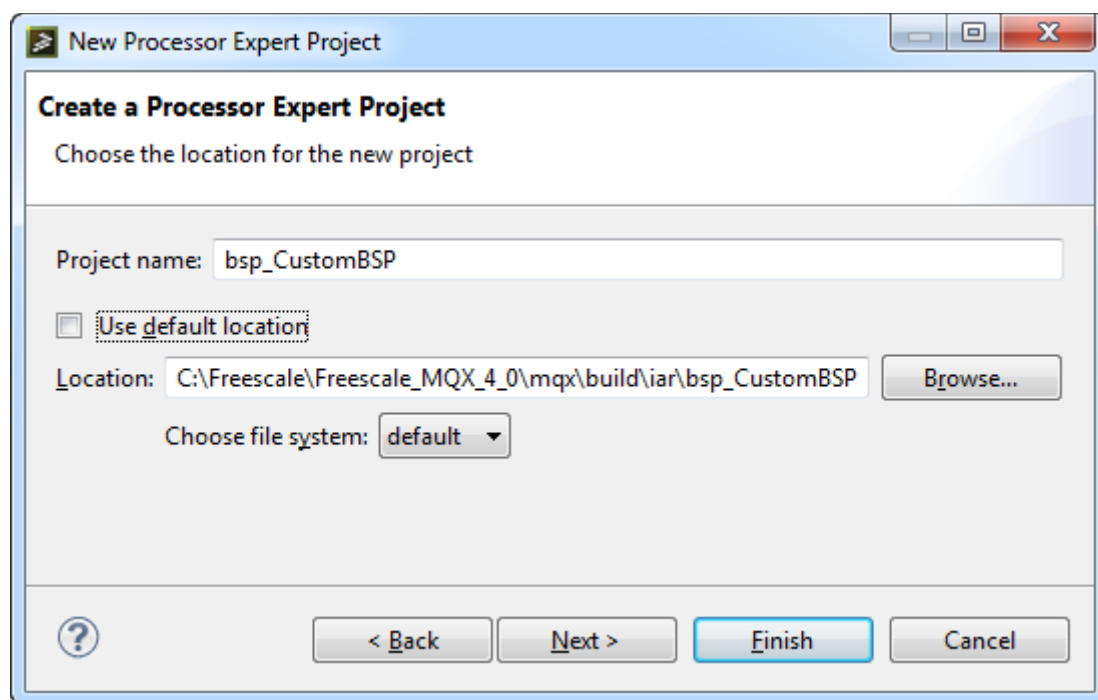


Figure 2: New PEx BSP Project

4. Select the device for the original BSP, in this case MK60DN512xxx10. This device is changed later.
5. Choose desired perspective. If unsure, use current perspective.
6. Select the IAR compiler and Finish.

4.1.2 Re-Use the PEx settings from CodeWarrior project

The CodeWarrior BSP project already has the CPU component setup for the cloned BSP. It's easiest to re-use that setup, and then modify as desired.

7. In PEx, close the **bsp_CustomBSP** project, by right-clicking on the project and select **Close Project**.
8. Copy the ProcessorExpert.pe file from the CodeWarrior BSP project directory to the IAR BSP project directory, overriding the file just created in the new project. In this case copy:
`\mqx\build\cw10\bsp_CustomBSP\ProcessorExpert.pe`
to
`\mqx\build\iar\bsp_CustomBSP\ProcessorExpert.pe`
9. Re-open the project in PEx by right-clicking the project and selecting **Open Project**.
10. Eclipse may give an error, such as **Resource is out of sync with the file system**. Right-click the project and click **Refresh**.
11. Copying the CodeWarrior file changed the compiler settings. To change it back, select the CPU component in the Components View. In the Component Inspector, select the **Build options** tab. Change the Compiler to IAR.

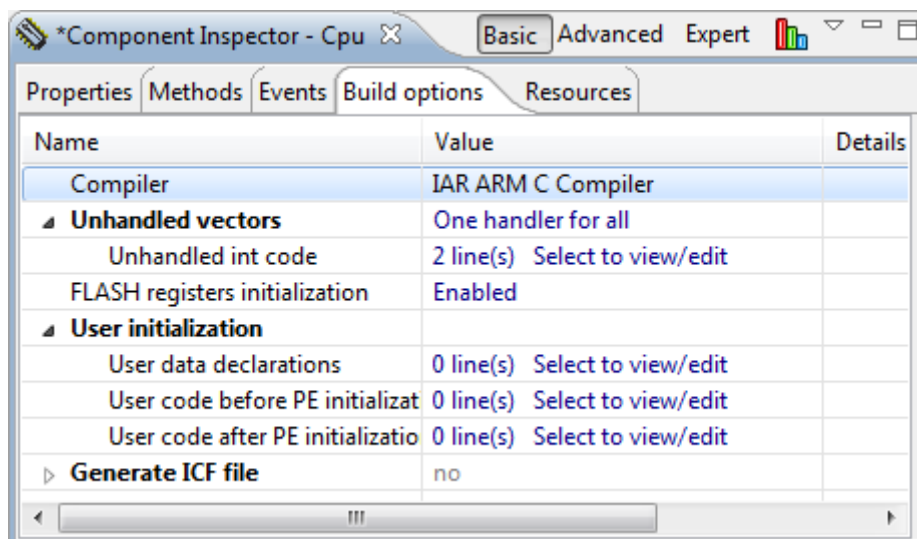


Figure 3: Change compiler in PEx to IAR

4.1.3 Generate the PEx code for the BSP

12. The file **ProcessorExpert.c** in the sources folder conflicts with MQX. Remove it from the project by right-clicking on it and selecting **Delete**.
13. Click the **Generate Code** button.

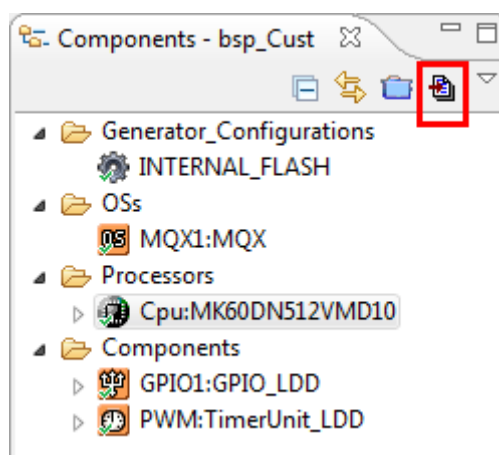


Figure 4: Generate Code in PEx

4.1.4 Update the IAR BSP project to use PEx

IAR has a feature called Project Connection that allows IAR to import an XML file from PEx with most of the project settings. However, as of EWARM v6.50.2, there are still several things to manually change in the project.

14. Open the custom BSP workspace in IAR, in this case **\build\CustomBSP\iar\build_libs.eww**
15. Be sure that the BSP project is the active project. If not bold, right-click on the project and select **Set as Active**.
16. Enable Project Connections in IAR. Use the menu **Tools->Options**. Check the box **Enable Project Connects** in the project options. Click **OK** to save.

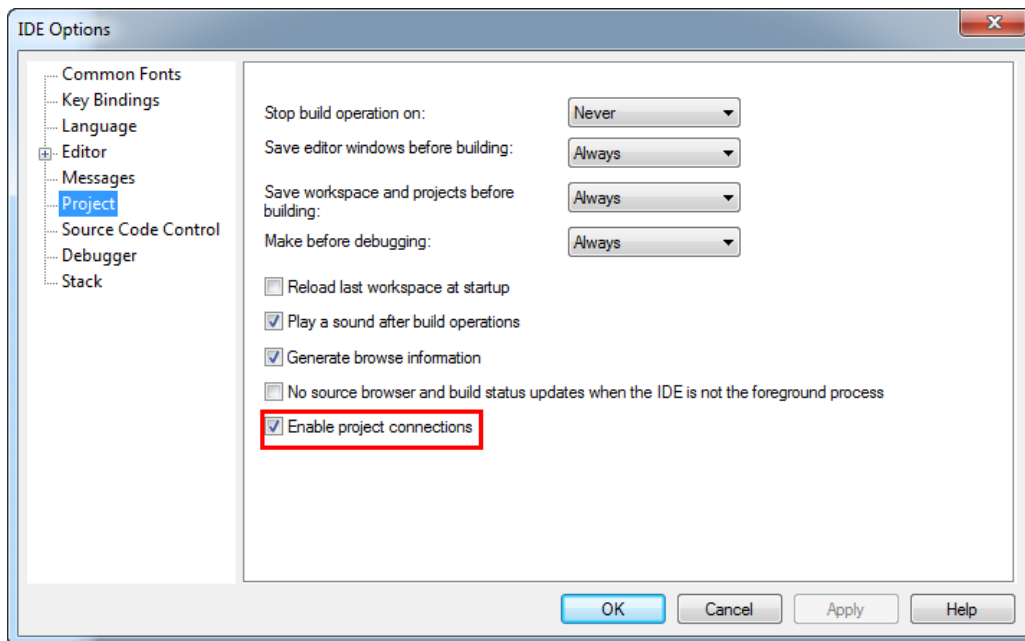


Figure 5: Enable Project Connections in IAR

17. Add a connection to PEx using the menu **Project->Add Project Connection**.
18. Connect using **Freescall Processor Expert**.
19. Browse to the ProjectInfo.xml file generated by PEx. In this case, **\mqx\build\iar\bsp_CustomBSP\ProjectInfo.xml**. Click **Open**. This has added the source files from PEx and the compiler paths to the project.
20. Update compiler search path ordering. PEx adds definitions and functions already included in the BSP, so it is important to set up the toolchain to use the PEx generated code instead of the existing files. Right-click the BSP project and select **Options**. The project connection has already added the two paths below in the **C/C++ Compiler->Preprocessor settings**. They need to be moved to the top of the include directories to ensure that the compiler finds the PEx headers first:
\mqx\build\iar\bsp_CustomBSP\Sources
\mqx\build\iar\bsp_CustomBSP\Generated_Code

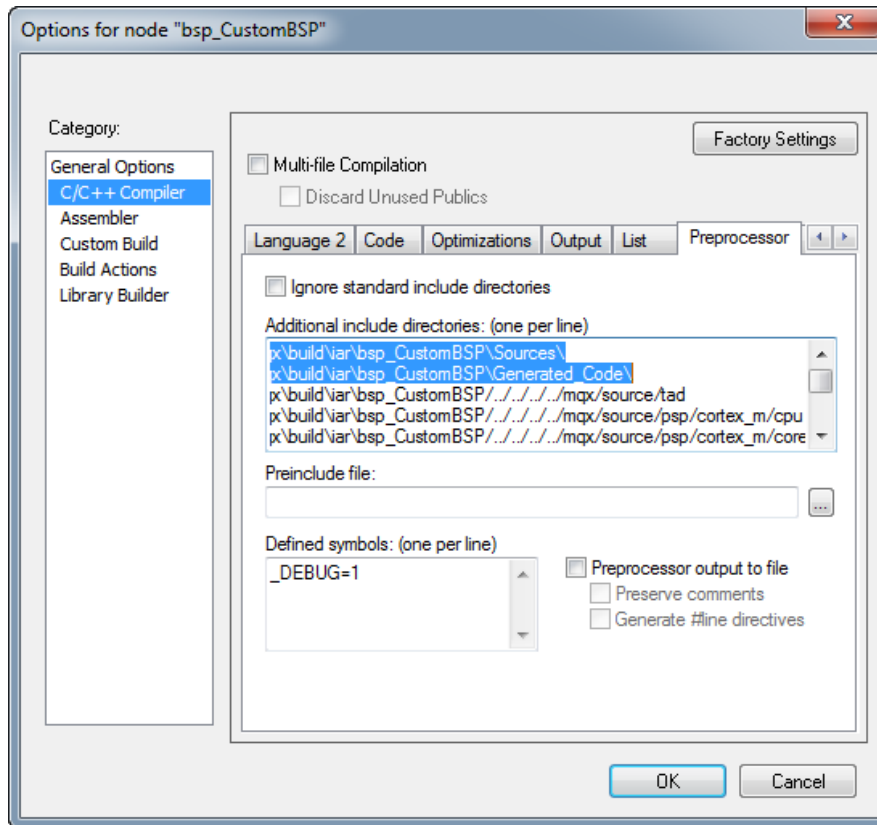


Figure 6: IAR BSP Preprocessor Setting Changes

4.1.5 Update IAR BSP Batch File for PEX

MQX uses batch files to copy the header files required by the applications to the **lib** folder. The BSP batch file needs to be updated to copy the PEX files to the lib folder. The code from the CodeWarrior section can be re-used.

21. Edit the BSP batch file, in this case `\mqx\build\bat\bsp_CustomBSP.bat`. Note that in Windows, double-clicking on the batch file executes it. To edit it, right-click and select **Edit**.
22. Find the CodeWarrior section under the label `:tool_cw10`. Find the lines related to `%OUTPUTDIR%\Generated_Code` and `%OUTPUTDIR%\Sources` and copy those lines.
23. Find the IAR section under the label `:tool_iar`. Paste the lines from above at the top of this section.
24. Modify the paths. Replace `cw10` with `iar`. Modify the filenames of the linker files. In this example, the modified IAR section looks like this:

```
:tool_iar
IF NOT EXIST %OUTPUTDIR%\Generated_Code mkdir %OUTPUTDIR%\Generated_Code
for /R %MQXROOTDIR%\mqx\build\iar\bsp_CustomBSP\Generated_Code %%f in (*.h) do copy %%f
%OUTPUTDIR%\Generated_Code\
IF NOT EXIST %OUTPUTDIR%\Sources mkdir %OUTPUTDIR%\Sources
for /R %MQXROOTDIR%\mqx\build\iar\bsp_CustomBSP\Sources %%f in (*.h) do copy %%f
%OUTPUTDIR%\Sources\
copy %MQXROOTDIR%\mqx\source\bsp\CustomBSP\iar\intflash.icf %OUTPUTDIR%\intflash.icf /Y
copy %MQXROOTDIR%\mqx\source\bsp\CustomBSP\iar\ram.icf %OUTPUTDIR%\ram.icf /Y
goto copy_end
```

25. Save the batch file.

4.1.6 Build the MQX Libraries

Test the changes are correct by building all MQX libraries for the **CustomBSP**.

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26. If the BSP project has already been built, it may need to be cleaned for the changes to take effect. Right-click the BSP project and select **Clean**.
27. Build the workspace using the menu **Project->Batch Build**. Select **Debug**, and hit the **Make** button. There should be no errors in these project builds.
28. Verify that the PEX headers are included in the **lib** folder for the applications. **Events.h** should be in the sources directory below, and there should be several files in the **Generated_Code** directory. If these files are missing, check the batch file, save it, clean the BSP, and rebuild it. In this case, the lib paths are:
\\lib\CustomBSP.iar\debug\bsp\Generated_Code
\\lib\CustomBSP.iar\debug\bsp\Sources

4.1.7 Test PEX changes with pe_demo

MQX provides an application demo to work with PEX in the BSP. These modifications to the BSP can be tested using the **pe_demo** application. At this point, the MCU derivative has not been changed from the original BSP. Therefore, the **pe_demo** can be run on the board associated with the original BSP to test it, in this case the TWR-K60D100M board.

29. Add the **pe_demo** project to the IAR workspace. Use menu **Project->Add Existing Project**. Browse to the **pe_demo** project for the custom BSP, in this case **\\demo\pe_demo\iar\pe_demo_CustomBSP\pe_demo_CustomBSP.ewp**. Click **Open**.

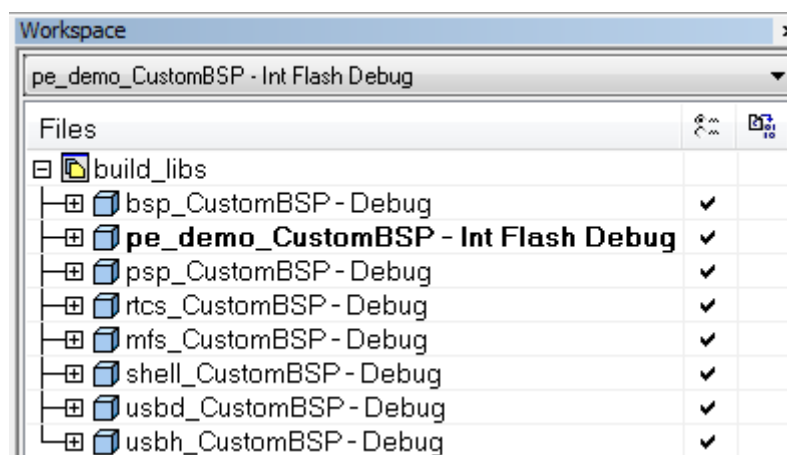


Figure 7: **pe_demo** project added to IAR workspace

30. Add PEX header paths. The applications need two paths added that point to header files located in the PEX Driver Suite installation. These two paths are already included in the BSP project settings from the Project Connection. Copy the two paths below from the BSP project and add to the **pe_demo** project settings in **C/C++Compiler->Preprocessor**, at the top of the list. Click **OK** to save.
<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\iofiles
<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\pdd\inc

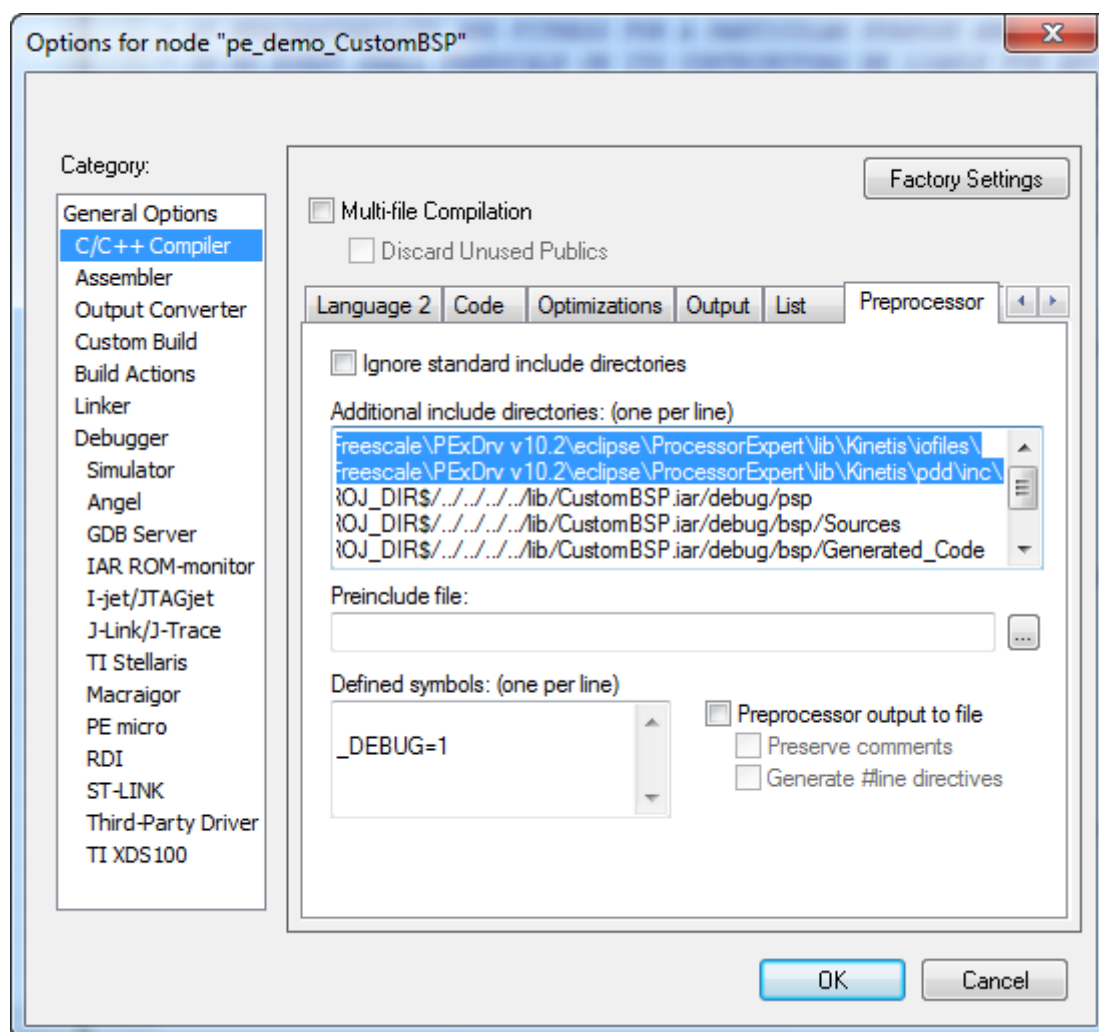


Figure 8: PEX paths added to pe_demo in IAR

31. Build the **pe_demo** project. There should be no errors.
32. Download and test **pe_demo** on the board for the original BSP, in this case TWR-K60D100M board.

4.2 Setting up BSP for PEX with Keil μ Vision[®]

As of MQX v4.0.2, the BSP project did not include PEX support. These steps show how to use the PEX Driver Suite and add PEX support to the BSP.

4.2.1 Adding PEX Driver Suite Project

1. In PEX, create a new PEX project using the menu File->New->Processor Expert Project
2. Name the project the same name as the BSP project, in this case bsp_CustomBSP
3. Do not use the default location, instead create the project in the BSP project directory for Keil, in this case \mqx\build\uv4\bsp_CustomBSP. NOTE: the tool will default to creating a subdirectory under bsp_CustomBSP with the same name. Be sure to correct the path so the PEX project is created in the same directory as the Keil project. The warning caused by this is OK.

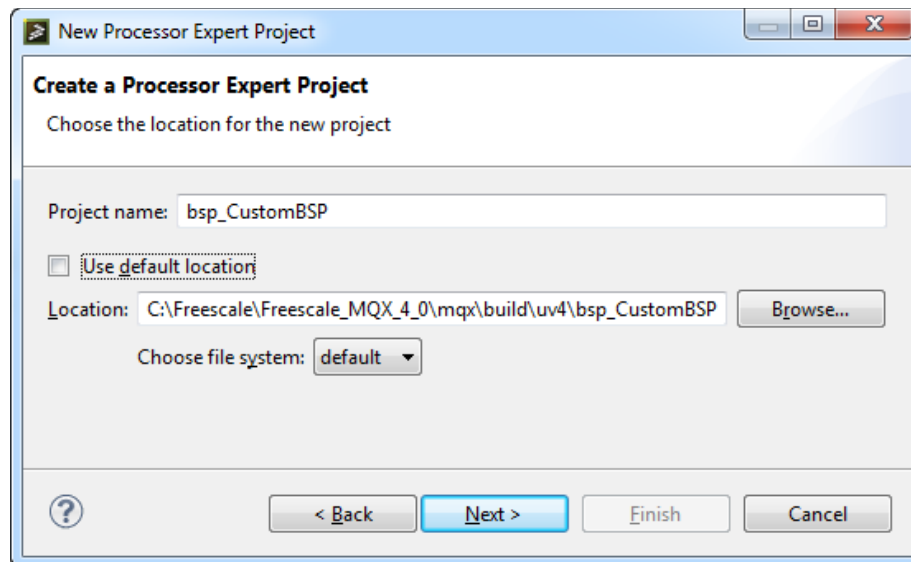


Figure 9: New PEx BSP Project for Keil

4. Select the device for the original BSP, in this case MK60DN512xxx10. This device will be changed later.
5. Choose desired perspective, if unsure, use current perspective.
6. Select the Keil compiler and **Finish**.

4.2.2 Re-Use the PEx settings from CodeWarrior project

The CodeWarrior BSP project already has the CPU component setup for the cloned BSP. It's easiest to re-use that setup, and then modify as desired.

7. In PEx, close the **bsp_CustomBSP** project, by right-clicking on the project and select **Close Project**.
8. Copy the **ProcessorExpert.pe** file from the CodeWarrior BSP project directory to the Keil BSP project directory overriding the file just created in the new project. In this case copy:
`\mqx\build\cw10\bsp_CustomBSP\ProcessorExpert.pe`
to
`\mqx\build\uv4\bsp_CustomBSP\ProcessorExpert.pe`
9. Re-open the project in PEx by right-clicking the project and selecting **Open Project**.
10. Eclipse may give an error, such as **Resource is out of sync with the file system**. Right-click the project and click **Refresh**.
11. Copying the CodeWarrior file changed the compiler settings. To change it back, select the CPU component in the Components View. In the Component Inspector, select the **Build options** tab. Change the compiler to Keil.

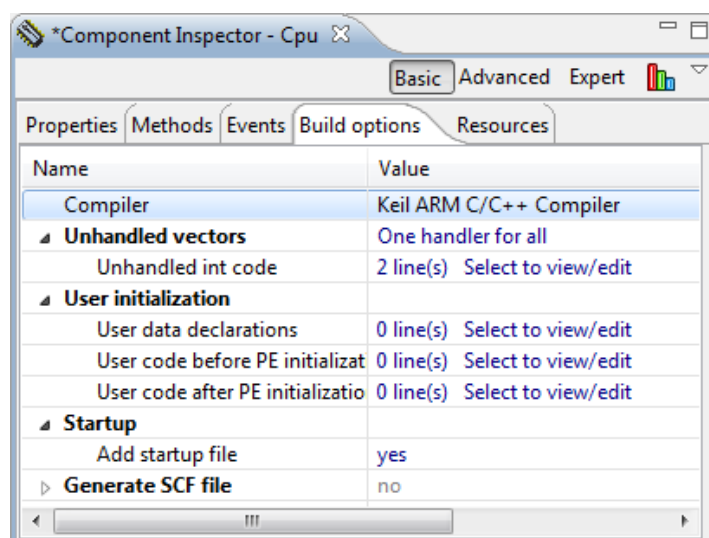


Figure 10: Change compiler in PEx to Keil

4.2.3 Generate the PEx code for the BSP

12. The file **ProcessorExpert.c** in the Sources folder conflicts with MQX. Remove it from the project by right-clicking on it, and select **Delete**.
13. Click the **Generate Code** button.

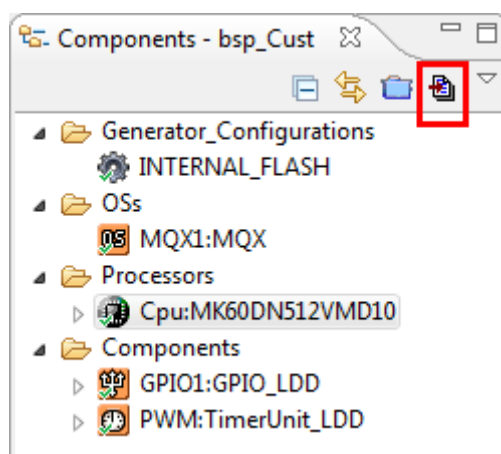


Figure 11: Generate Code in PEx

4.2.4 Update the Keil BSP project to use PEx

14. Open the custom BSP workspace in Keil, in this case **\build\CustomBSP\uv4\build_libs.uvmpw**
15. Be sure that the BSP project is the active project. If not highlighted, right-click on the project and select **Set as Active Project**.
16. Add the PEx source files to the BSP project. Right-click the build configuration **bsp_CustomBSP Debug** and select **Add Group**. Find **New Group** added to the bottom of the list of groups in the project. Rename it by selecting, hit **F2**, and rename to **Generated_Code**. Right-click on **Generated_Code** group and select **Add files to group**. Navigate to the PEx **Generated_Code** directory, in this case **\mqx\build\uv4\bsp_CustomBSP\Generated_Code**. Add all source files in this directory.

17. Navigate to the directory `\mqx\build\uv4\bsp_CustomBSP\Project_Settings\Startup_Code` and add the source file `startup_ARM_CC.c`. Then click the **Close** button.
18. Repeat the steps above to add the group Sources, and add the file **Events.c** in the directory `\mqx\build\uv4\bsp_CustomBSP\Sources`.

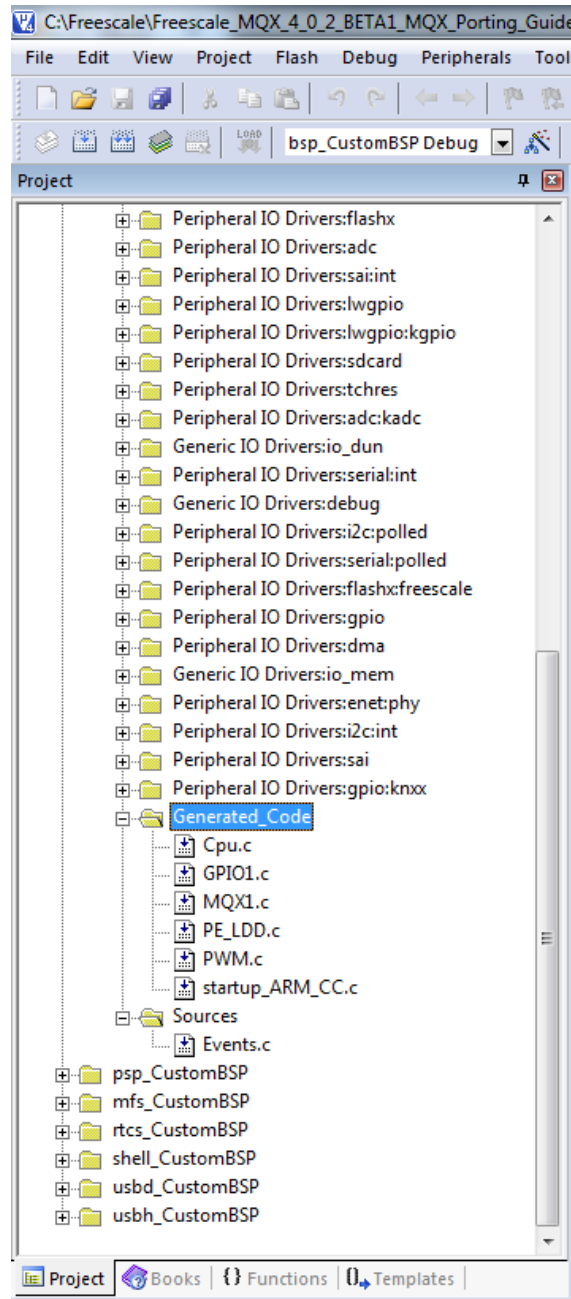


Figure 12: PEX source files added to Keil BSP project

19. Open the **ProjectInfo.xml** file. PEX generates an XML file with the files and paths used by PEX to be added to the tool chain project. For Keil, it can be a useful reference to find the paths required. In this case, use a text editor to open the file `\mqx\build\uv4\bsp_CustomBSP\ProjectInfo.xml`.
20. Copy the PEX include paths. There are two paths used by PEX header files. These paths need to be added to the compiler include paths. In **ProjectInfo.xml**, find these two include

paths:

<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\iofiles\
<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\pdd\inc\

21. Modify the Keil compiler include paths. In Keil, open the options for the BSP project. Right-click the build configuration **bsp_CustomBSP Debug**, select **Options for bsp_CustomBSP**. Click the **C/C++** tab. Place the cursor at the beginning of the **Include Paths** field. Copy and paste the two paths in the step above from the XML file into the include paths in Keil. Place a semicolon after each path. NOTE: be sure that these paths contain no spaces.
22. Add the PEX generated header file paths to the project. After the include paths added in the step above, add these include paths with semicolons after each path. In this case, the four paths to copy to the Include Paths field are like this:
C:\Freescale\PEXDrv_v10.2\eclipse\ProcessorExpert\lib\Kinetis\iofiles\;C:\Freescale\PEXDrv_v10.2\eclipse\ProcessorExpert\lib\Kinetis\pdd\inc\;.\Generated_Code\;.\Sources;
23. Verify the include paths. Click the browse button to the right of the Include Paths field. The PEX paths should be first in the list, similar to this image:

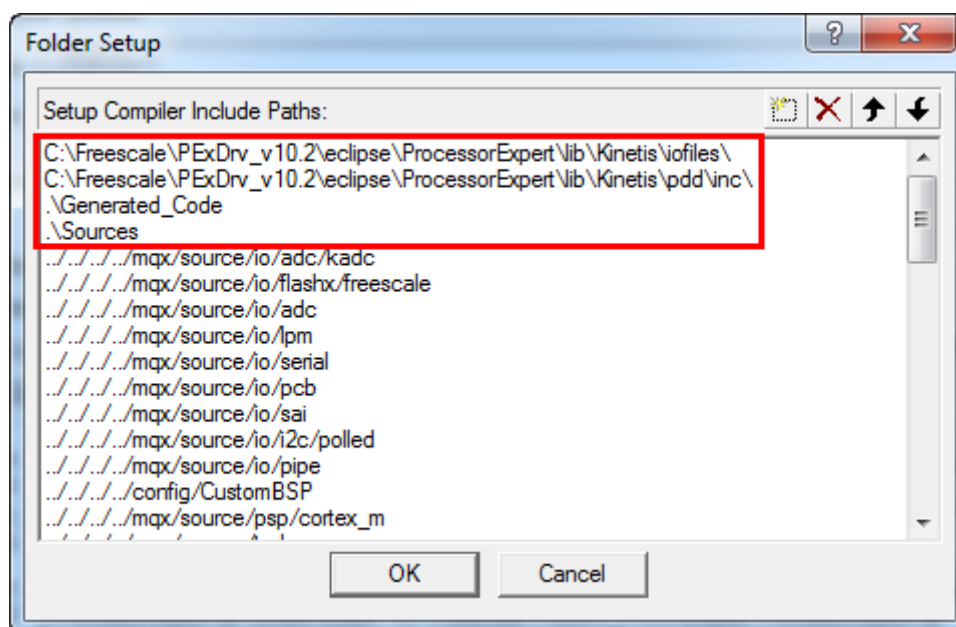


Figure 13: PEX include paths added to Keil

24. Click the **OK** button twice to save the project settings.

4.2.5 Update Keil BSP Batch File for PEX

MQX uses batch files to copy the header files required by the applications to the **lib** folder. The BSP batch file needs to be updated to copy the PEX files to the lib folder. The code from the CodeWarrior section can be re-used.

25. Edit the BSP batch file, in this case **\mqx\build\bat\bsp_CustomBSP.bat**. Note that in Windows double-clicking on the batch file executes it. To edit it, right-click and select **Edit**.
26. Find the CodeWarrior section under the **label :tool_cw10**. Find the lines related to **%OUTPUTDIR%\Generated_Code** and **%OUTPUTDIR%\Sources**, and copy those lines.
27. Find the Keil section under the **label :tool_uv4**. Paste the lines from above at the top of this section.

28. Modify the paths. Replace cw10 with uv4. Modify the filenames of the linker files. In this example, the modified Keil section looks like this:

```
:tool_uv4
IF NOT EXIST %OUTPUTDIR%\Generated_Code mkdir %OUTPUTDIR%\Generated_Code
for /R %MQXROOTDIR%\mqx\build\uv4\bsp_CustomBSP\Generated_Code %%f in (*.h) do copy %%f
%OUTPUTDIR%\Generated_Code\
IF NOT EXIST %OUTPUTDIR%\Sources mkdir %OUTPUTDIR%\Sources
for /R %MQXROOTDIR%\mqx\build\uv4\bsp_CustomBSP\Sources %%f in (*.h) do copy %%f
%OUTPUTDIR%\Sources\
copy %MQXROOTDIR%\mqx\source\bsp\CustomBSP\uv4\intflash.scf %OUTPUTDIR%\intflash.scf /Y
goto copy_end
```

29. Save the batch file.

4.2.6 Build the MQX Libraries

Test the changes are correct by building all MQX libraries for the **CustomBSP**.

30. If the BSP project has already been built, it may need to be cleaned for the changes to take effect. Use the menu **Project->Clean bsp_CustomBSP(bsp_CustomBSP Debug)**.
31. Build the workspace using the menu **Project->Batch Build**. In this case, only the Debug build targets need to be built.
32. Verify the PEX headers are included in the **lib** folder for the applications. **Events.h** should be in the Sources directory, and there should be several files in the **Generated_Code** directory. If these files are missing, check the batch file, save it, clean the BSP, and rebuild it. In this case, the lib paths are:
\\lib\CustomBSP.uv4\debug\bsp\Generated_Code
\\lib\CustomBSP.uv4\debug\bsp\Sources

4.2.7 Test PEX changes with pe_demo

MQX provides an application demo to work with PEX in the BSP. These modifications to the BSP can be tested using the **pe_demo** application. At this point, the MCU derivative has not been changed from the original BSP. Therefore, the **pe_demo** can run on the board associated with the original BSP to test it, in this case the TWR-K60D100M board.

33. Add the **pe_demo** project to the Keil workspace. Use the menu **Project->Manage->Multi-Project Workspace**. Click the **New** button. Browse to the **pe_demo** project for the custom BSP, in this case
\\demo\pe_demo\uv4\pe_demo_CustomBSP\pe_demo_CustomBSP.uvproj. Click **Open**. Click **OK** to save the workspace.

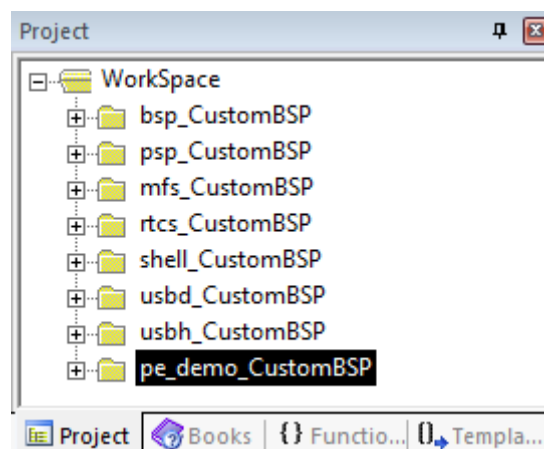


Figure 14: **pe_demo** project added to Keil workspace

34. Add PEX header paths. The applications will need two paths added that point to header files located in the PEX Driver Suite installation. These are the same paths added earlier to the BSP. Copy the two paths from the BSP project and add to the **pe_demo** project in the compiler Include Paths. Click **OK** twice to save.

**<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\iofiles\
<PEX Driver Suite Installation>\eclipse\ProcessorExpert\lib\Kinetis\pdd\inc**

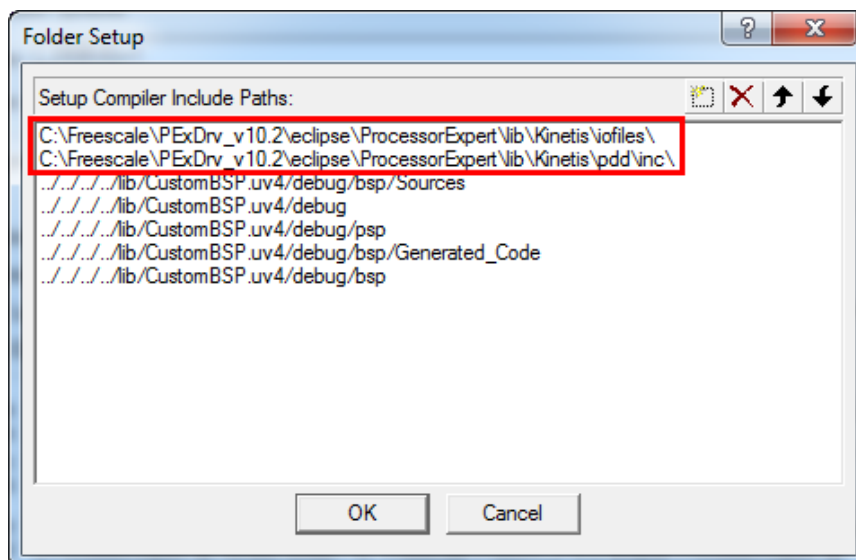


Figure 15: PEX paths added to **pe_demo** in Keil

35. Build the **pe_demo** project. There should be no errors.
36. Download and test **pe_demo** on the board for the original BSP, in this case TWR-K60D100M board.

5 Changing MCU derivative in MQX projects

If the device used in the customized BSP is different than the original BSP, the MCU derivative needs to be changed.

5.1 Changing the PEX Package

If PEX is used, PEX may be able to change the package instead of the CPU Component. This minimizes the steps in using PEX with the BSP because the original BSP CPU properties are preserved. To change the package, select the CPU Component in the Components View. In the Component Inspector, under the Properties Tab, select the CPU type property. The available packages for that device are shown. If the desired part number is not available, the CPU Component needs to be changed, detailed in the next section.

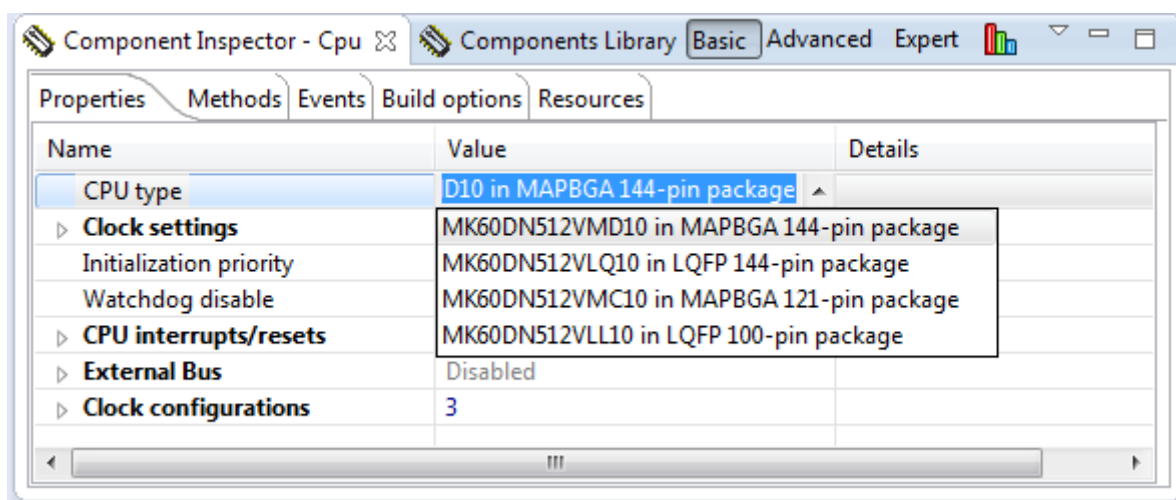


Figure 16: Changing Package in PEx

5.2 Changing the PEx CPU Component

If PEx is used, these steps describe changing the MCU derivative in the MQX BSP. In addition, these documents installed with MQX have further details about managing the BSP project with PEx.

- *How-to Change Default Clock Settings in Kinetis BSPs* located in \doc\tools\cw.
- *CW for Microcontrollers V10 and MQX™* located in \doc\tools\cw.

Unfortunately, this step loses the CPU settings from the original CPU component. Use the original CPU component as a reference.

1. Open the PEx BSP project.

2. Add a new CPU component. In the Component Library View, under the Processors Tab, navigate to the new CPU. In this case, MK40DX256xxx10. Double-click the component to add to the project.

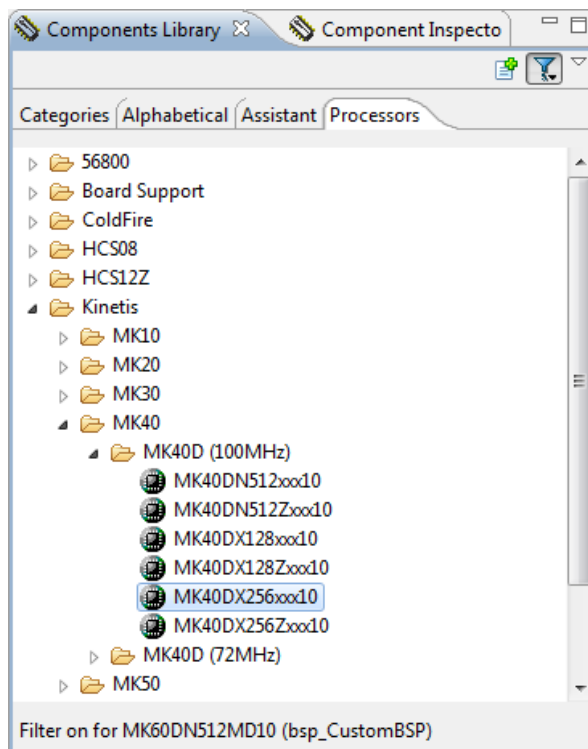


Figure 17: New CPU component in Components Library

3. Select the desired package, in this case MK40DX256VMD10 144-pin MAPBGA. The CPU configurations are not important in this project since MQX doesn't use PEx to generate the linker command files. Click **Next**.
4. Select the desired compiler. Click **Finish**.
5. The new CPU component is added to the project and the old one is still present but disabled. The old component's settings can still be viewed for guidance on setting up the new component.

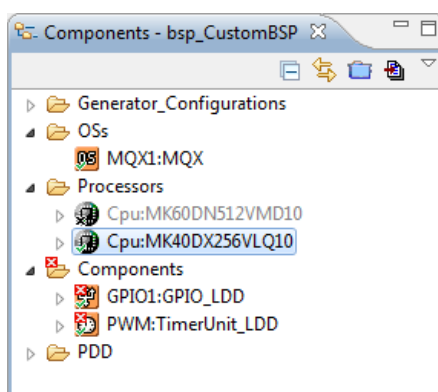


Figure 18: New CPU Component in BSP project

6. Change the internal peripheral settings. To avoid conflicts with MQX source code, some features setup by PEx should be disabled. In the Component Inspector View, under the

Properties Tab, expand the Internal Peripherals group. Disable the NMI pin and Flash Configuration properties:

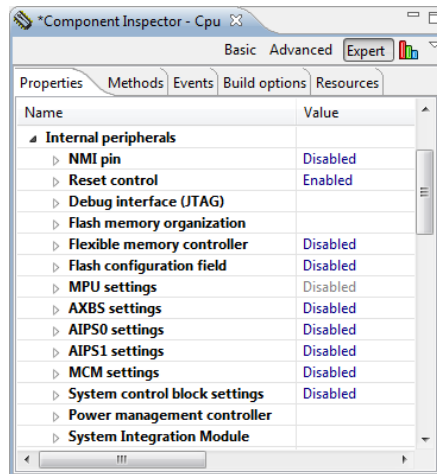


Figure 19: PEx Internal Peripheral Settings

7. The existing peripheral components may have errors after the CPU change, caused by changes in pin names and clock frequencies. Clean up the errors, or remove the unnecessary components. In this case, fix the counter frequency of the PWM component if needed, and change the pins used in the GPIO1 component as shown in this list:
 - LED1 PTC7
 - LED2 PTC8
 - LED3 PTC9
 - LED4 PTC11
8. Generate the PEx code.

5.3 Specify MCU derivative in MQX

MQX uses macros for the MCU derivative, board specifics, and derivative header files.

9. Find driver files dependent on the MCU derivative. **User_config.h** uses the macro **MQX_CPU** to define the derivative in the BSP. In this case, the derivative is defined as **PSP_CPU_MK60D100M**. The file `\mqx\source\psp\cortex_m\kinetis.h` uses this derivative to include the correct header file. In this case, the header file is `\mqx\source\psp\cortex_m\cpu\MK60D10.h`. The top of this header file defines an MCU derivative, in this case **MCU_MK60D10**. Search the BSP project to find driver files that reference this macro and make a note of these files because they may need to be modified after the derivative is changed (see Section [5.4 Modifying Driver Derivative Files](#)). In this case, there is one driver file below that references **MCU_MK60D10**: `\mqx\source\io\sai\sai_mk60.c`
10. Modify MCU derivative in **user_config.h**. MQX already has a list of several supported derivatives in `\Freescall MQX_4_0\mqx\source\psp\cortex_m\kinetis.h`. Find the derivative macro for the customized BSP and update **user_config.h** with this derivative. In this case, the line below in **user_config.h** is modified for the desired K40:

```
#define MQX_CPU                PSP_CPU_MK40DX256
```

11. If the desired derivative is not in the list in **kinetis.h**, it can be added. An example is the device MK20DN512VLK10. A BSP for this derivative can also be cloned from TWR-K60D100M, but the MQX release has no support for this derivative. In this case, the lines below are added to kinetis.h:

```
#elif (MQX_CPU == PSP_CPU_MK20DN512)
#include "MK20D10.h"
```

12. If the desired derivative header file is missing from the MQX release, add it. Find the desired header file in the toolchain directory listed below. Copy the header file to **\mqx\source\psp\cortex_m\cpu**.

- **<CodeWarrior Installation>\MCU\lib\wizard_data\ARM\DataBase\derivatives**
- **IAR: <IAR Installation>\arm\inc\Freescale**
- **Keil: <Keil Installation>\ARM\INC\Freescale\Kinetis**

13. Update the PSP batch file if the derivative header file is changed. In this example, modify the batch file found at **\mqx\build\bat\psp_CustomBSP.bat**:

```
copy %MQXROOTDIR%\mqx\source\psp\cortex_m\cpu\MK40D10.h %OUTPUTDIR%\MK40D10.h /Y
```

14. If the PSP_CPU_ macro used in **user_config.h** was newly added to **kinetis.h**, there is one more step to define the new macro. **Edit \mqx\source\psp\cortex_m\psp_cpudef.h** and add a new entry for the new CPU Identification macro, like this:

```
#define PSP_CPU_MK20DN512 (PSP_CPU_NUM(PSP_CPU_ARCH_ARM_CORTEX_M4,
PSP_CPU_GROUP_KINETIS_K2X, 0xE))
```

5.4 Modifying Driver Derivative Files

15. Review the derivative specific driver source files for the desired derivative. If needed, modify the files, or change the BSP project to use a different source file for the desired sub-family. In this case, the source files used in the BSP are changed as follows:

- **\mqx\source\io\sai\sai_mk40.c** instead of **sai_mk60.c**

6 Clock Configuration

In this example, the BSP needs the clock source changed from a 50 MHz oscillator to an 8 MHz crystal. Also, the example changes the PLL output from 96 MHz to 48 MHz, to force a change to the USB clock dividers, and detail these steps.

6.1 Changing Clock Configuration with PEx

These steps assume PEx is already included in the BSP project, see [Using Processor Expert \(PEX\) in the BSP](#).

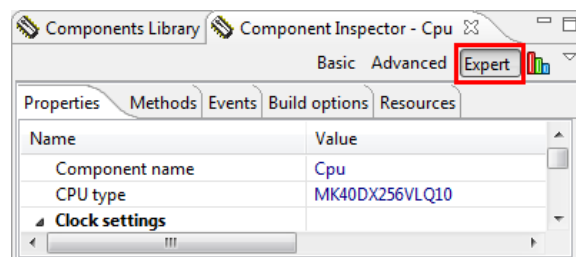


Figure 20: Expert Mode in Component Inspector

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It is recommended to use Expert mode in the Component Inspector to see all property options for the PEx component. To use Expert mode, click the Expert button in the upper right corner of the Component Inspector View.

6.1.1 Configure the Clock Settings

Use the Component Inspector View to configure the CPU component. Expand the Clock Settings properties group.

1. Internal Oscillator: these settings generally do not need to be changed. This example leaves them in their default settings.
2. RTC Oscillator: If the BSP uses the RTC peripheral with the 32 kHz oscillator, this oscillator needs to be enabled. In this example, the TWR-K40D100M board includes a 32 kHz crystal, and the RTC oscillator is enabled with no load capacitors added.
3. System Oscillator 0: this should be enabled and configured if any external clock source is used. In this example, the BSP requires an external clock source for USB. The TWR-K40D100M board uses an 8 MHz crystal. No load capacitors are added and set oscillator operating mode to Low Power.

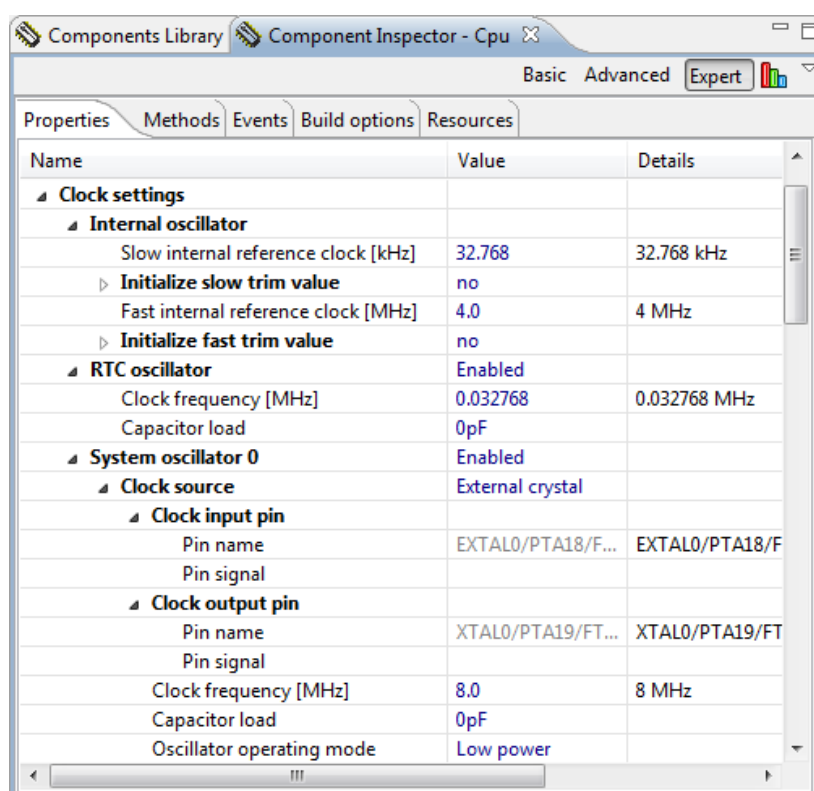


Figure 21: PEx Clock Settings

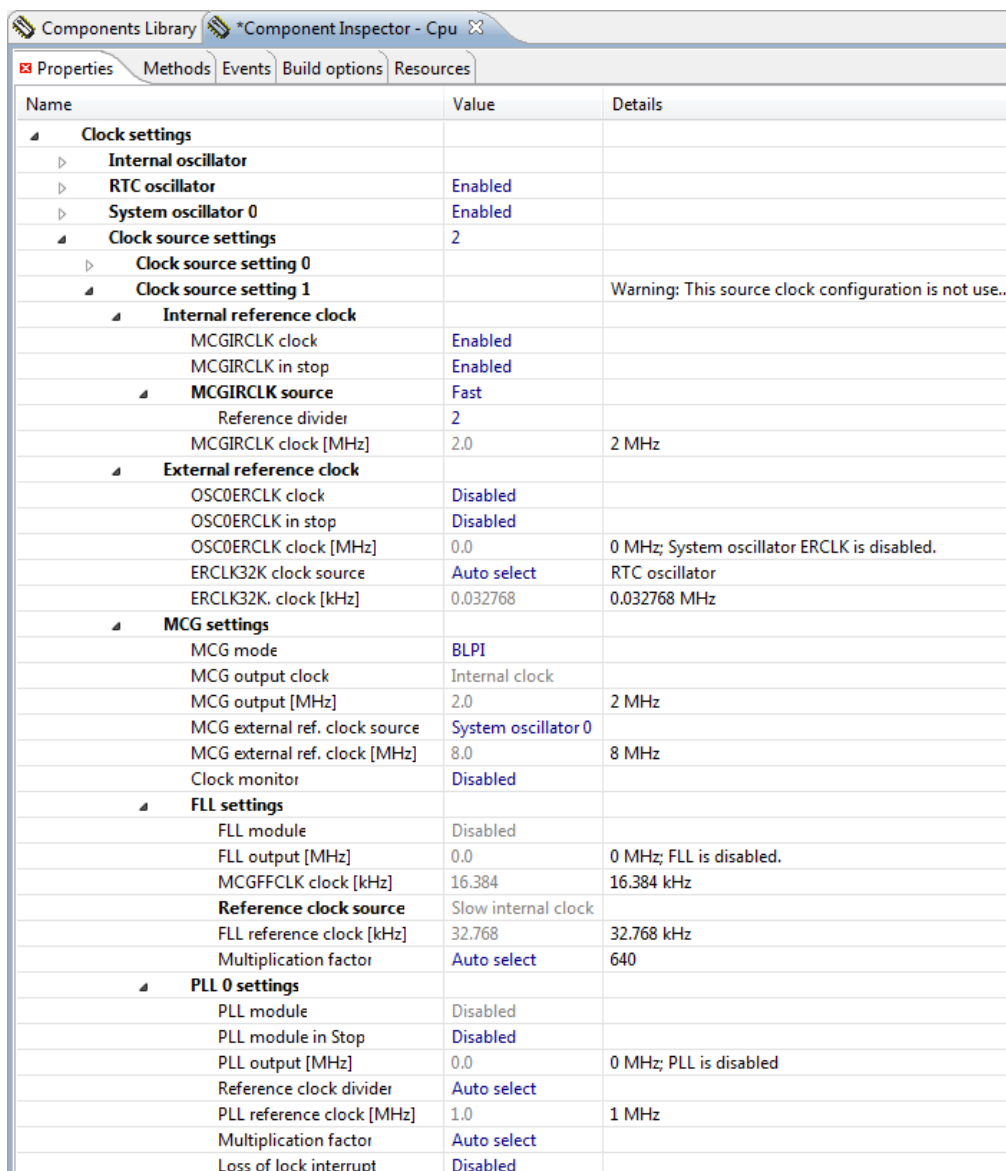
4. Clock Source Settings: the Kinetis BSPs in MQX are enabled for low-power modes. To enable this, there are generally two Clock Source Settings. The first is for Run mode with the clock frequencies running at their maximum for the BSP. The second is for VLPR mode, running from the internal fast oscillator. In this example, the BSP uses these two Clock Source Settings. Change the number of Clock Source Settings to 2.

5. Clock Source Setting 0: this is the setting for RUN mode. In this example, it uses the 8 MHz crystal. Use the MCG in PEE mode to multiply the PLL Output clock up to 48 MHz.

Components Library Component Inspector - Cpu		
Properties Methods Events Build options Resources		
Name	Value	Details
▲ Clock settings		
▶ Internal oscillator		
▶ RTC oscillator	Enabled	
▶ System oscillator 0	Enabled	
▲ Clock source settings	2	
▲ Clock source setting 0		
▲ Internal reference clock		
MCGIRCLK clock	Disabled	
MCGIRCLK in stop	Disabled	
MCGIRCLK source	Slow	
MCGIRCLK clock [MHz]	0.0	0 MHz; IRCLK is not enabled.
▲ External reference clock		
OSC0ERCLK clock	Enabled	
OSC0ERCLK in stop	Enabled	
OSC0ERCLK clock [MHz]	8.0	8 MHz
ERCLK32K clock source	RTC oscillator	0.032768 MHz
ERCLK32K clock [kHz]	0.032768	0.032768 MHz
▲ MCG settings		
MCG mode	PEE	
MCG output clock	PLL clock	
MCG output [MHz]	48.0	48 MHz
MCG external ref. clock source	System oscillator 0	
MCG external ref. clock [MHz]	8.0	8 MHz
Clock monitor	Enabled	
▲ FLL settings		
FLL module	Disabled	
FLL output [MHz]	0.0	0 MHz; FLL is disabled.
MCGFFCLK clock [kHz]	15.625	15.625 kHz
▲ Reference clock source	External clock	
Reference clock divider	Auto select	256
FLL reference clock [kHz]	31.25	31.25 kHz
Multiplication factor	Auto select	640
▲ PLL 0 settings		
PLL module	Enabled	
PLL module in Stop	Disabled	
PLL output [MHz]	48.0	48 MHz
Reference clock divider	Auto select	4
PLL reference clock [MHz]	2.0	2 MHz
Multiplication factor	Auto select	24
Loss of lock interrupt	Disabled	

Figure 22: PEx Clock Source Setting 0

6. Clock Source Setting 1: this is the setting for the VLPR low-power mode. In this example, it uses the fast internal oscillator in BLPI mode with a 2 MHz output clock from the MCG.



Name	Value	Details
▲ Clock settings		
▶ Internal oscillator		
▶ RTC oscillator	Enabled	
▶ System oscillator 0	Enabled	
▲ Clock source settings	2	
▶ Clock source setting 0		
▲ Clock source setting 1		Warning: This source clock configuration is not use...
▲ Internal reference clock		
MCGIRCLK clock	Enabled	
MCGIRCLK in stop	Enabled	
▲ MCGIRCLK source	Fast	
Reference divider	2	
MCGIRCLK clock [MHz]	2.0	2 MHz
▲ External reference clock		
OSC0ERCLK clock	Disabled	
OSC0ERCLK in stop	Disabled	
OSC0ERCLK clock [MHz]	0.0	0 MHz; System oscillator ERCLK is disabled.
ERCLK32K clock source	Auto select	RTC oscillator
ERCLK32K. clock [kHz]	0.032768	0.032768 MHz
▲ MCG settings		
MCG mode	BLPI	
MCG output clock	Internal clock	
MCG output [MHz]	2.0	2 MHz
MCG external ref. clock source	System oscillator 0	
MCG external ref. clock [MHz]	8.0	8 MHz
Clock monitor	Disabled	
▲ FLL settings		
FLL module	Disabled	
FLL output [MHz]	0.0	0 MHz; FLL is disabled.
MCGFFCLK clock [kHz]	16.384	16.384 kHz
Reference clock source	Slow internal clock	
FLL reference clock [kHz]	32.768	32.768 kHz
Multiplication factor	Auto select	640
▲ PLL 0 settings		
PLL module	Disabled	
PLL module in Stop	Disabled	
PLL output [MHz]	0.0	0 MHz; PLL is disabled
Reference clock divider	Auto select	
PLL reference clock [MHz]	1.0	1 MHz
Multiplication factor	Auto select	
Loss of lock interrupt	Disabled	

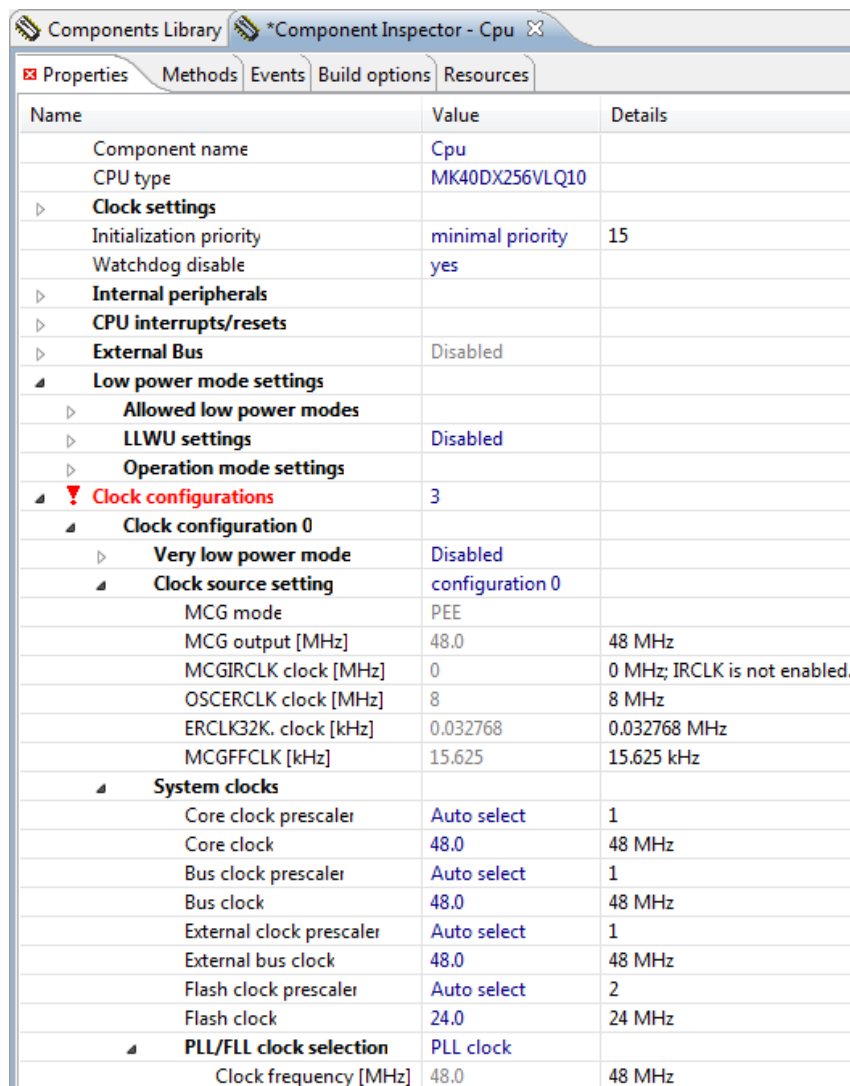
Figure 23: PEx Clock Source Setting 1

6.1.2 Clock Configurations

PEx allows for multiple clock configurations to dynamically change the clock settings. The MQX BSP takes advantage of this for low-power optimizations. In this example, the BSP uses 3 Clock Configurations.

7. Set the number of Clock Configurations to 3.

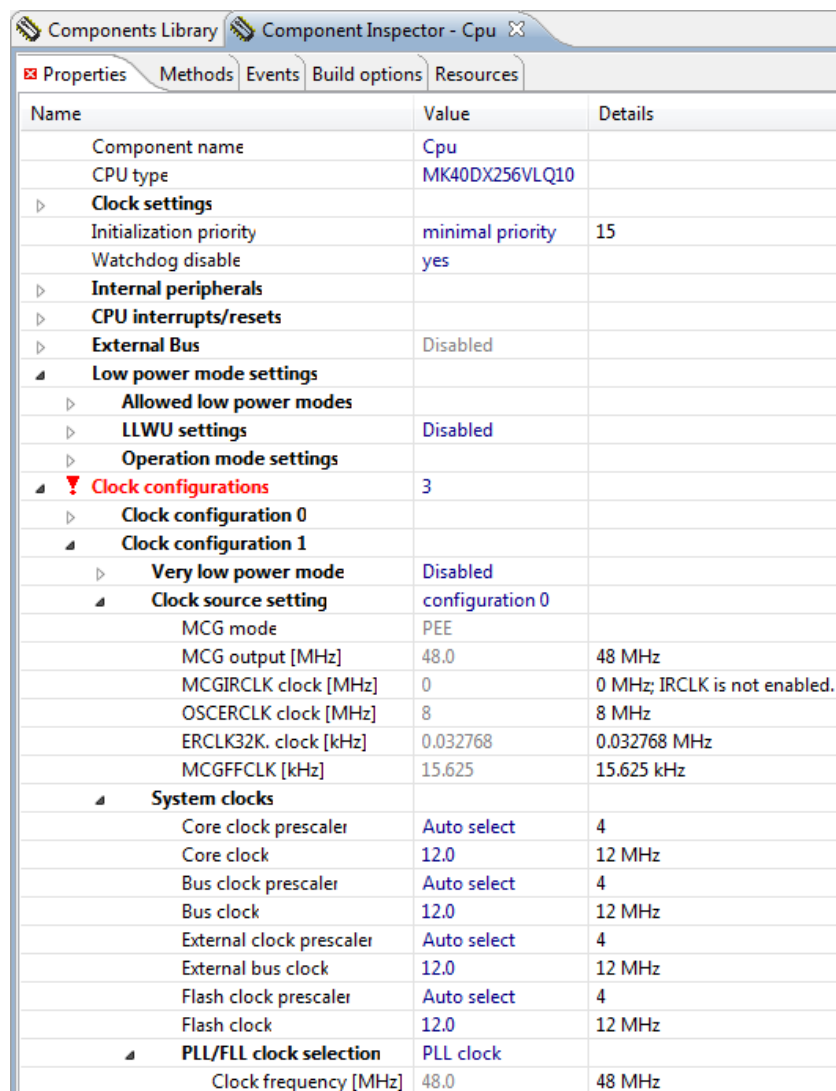
8. Clock Configuration 0: this is the main configuration for RUN mode, setting the Core Clock to 48 MHz, peripheral Bus Clock to 48 MHz, External Bus Clock to 48 MHz, and Flash Clock to 24 MHz using the PLL Clock.



Name	Value	Details
Component name	Cpu	
CPU type	MK40DX256VLQ10	
▶ Clock settings		
Initialization priority	minimal priority	15
Watchdog disable	yes	
▶ Internal peripherals		
▶ CPU interrupts/resets		
▶ External Bus	Disabled	
▲ Low power mode settings		
▶ Allowed low power modes		
▶ LLWU settings	Disabled	
▶ Operation mode settings		
▲ ⚠ Clock configurations	3	
▲ Clock configuration 0		
▶ Very low power mode	Disabled	
▲ Clock source setting	configuration 0	
MCG mode	PEE	
MCG output [MHz]	48.0	48 MHz
MCGIRCLK clock [MHz]	0	0 MHz; IRCLK is not enabled.
OSCERCLK clock [MHz]	8	8 MHz
ERCLK32K. clock [kHz]	0.032768	0.032768 MHz
MCGFFCLK [kHz]	15.625	15.625 kHz
▲ System clocks		
Core clock prescaler	Auto select	1
Core clock	48.0	48 MHz
Bus clock prescaler	Auto select	1
Bus clock	48.0	48 MHz
External clock prescaler	Auto select	1
External bus clock	48.0	48 MHz
Flash clock prescaler	Auto select	2
Flash clock	24.0	24 MHz
▲ PLL/FLL clock selection	PLL clock	
Clock frequency [MHz]	48.0	48 MHz

Figure 24: PEX Clock Configuration 0

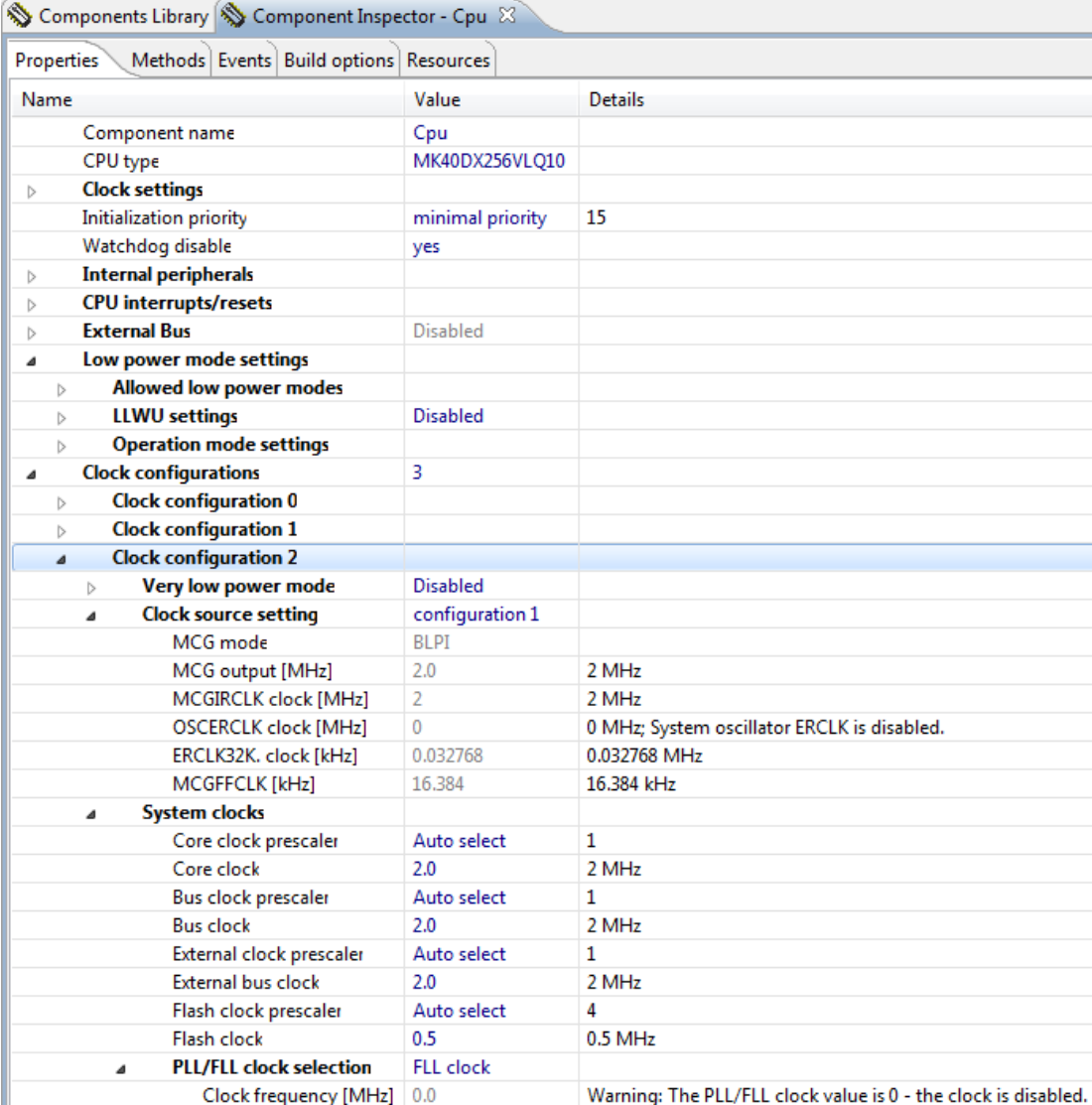
9. Clock Configuration 1: this configuration is used for the MCGAutoTrim method, which requires the Peripheral Bus Clock to be in that range of 8-16 MHz. This configuration uses the PLL Clock, and sets the Core Clock, Peripheral Bus Clock, External Bus Clock, and Flash Clock all to 12 MHz.



Name	Value	Details
Component name	Cpu	
CPU type	MK40DX256VLQ10	
▶ Clock settings		
Initialization priority	minimal priority	15
Watchdog disable	yes	
▶ Internal peripherals		
▶ CPU interrupts/resets		
▶ External Bus	Disabled	
▲ Low power mode settings		
▶ Allowed low power modes		
▶ LLWU settings	Disabled	
▶ Operation mode settings		
▲ ! Clock configurations	3	
▶ Clock configuration 0		
▲ Clock configuration 1		
▶ Very low power mode	Disabled	
▲ Clock source setting	configuration 0	
MCG mode	PEE	
MCG output [MHz]	48.0	48 MHz
MCGIRCLK clock [MHz]	0	0 MHz; IRCLK is not enabled.
OSCECLK clock [MHz]	8	8 MHz
ERCLK32K clock [kHz]	0.032768	0.032768 MHz
MCGFFCLK [kHz]	15.625	15.625 kHz
▲ System clocks		
Core clock prescaler	Auto select	4
Core clock	12.0	12 MHz
Bus clock prescaler	Auto select	4
Bus clock	12.0	12 MHz
External clock prescaler	Auto select	4
External bus clock	12.0	12 MHz
Flash clock prescaler	Auto select	4
Flash clock	12.0	12 MHz
▲ PLL/FLL clock selection	PLL clock	
Clock frequency [MHz]	48.0	48 MHz

Figure 25: PEx Clock Configuration 1

10. Clock Configuration 2: this configuration is used when running in VLPR mode. It uses the Clock Source Setting 1 setup previously and sets the Core Clock, Peripheral Bus Clock, and External Bus Clock all to 2 MHz, with the Flash Clock set to 0.5 MHz.



Name	Value	Details
Component name	Cpu	
CPU type	MK40DX256VLQ10	
▶ Clock settings		
Initialization priority	minimal priority	15
Watchdog disable	yes	
▶ Internal peripherals		
▶ CPU interrupts/resets		
▶ External Bus	Disabled	
▲ Low power mode settings		
▶ Allowed low power modes		
▶ LLWU settings	Disabled	
▶ Operation mode settings		
▲ Clock configurations	3	
▶ Clock configuration 0		
▶ Clock configuration 1		
▲ Clock configuration 2		
▶ Very low power mode	Disabled	
▲ Clock source setting	configuration 1	
MCG mode	BLPI	
MCG output [MHz]	2.0	2 MHz
MCGIRCLK clock [MHz]	2	2 MHz
OSCERCLK clock [MHz]	0	0 MHz; System oscillator ERCLK is disabled.
ERCLK32K. clock [kHz]	0.032768	0.032768 MHz
MCGFFCLK [kHz]	16.384	16.384 kHz
▲ System clocks		
Core clock prescaler	Auto select	1
Core clock	2.0	2 MHz
Bus clock prescaler	Auto select	1
Bus clock	2.0	2 MHz
External clock prescaler	Auto select	1
External bus clock	2.0	2 MHz
Flash clock prescaler	Auto select	4
Flash clock	0.5	0.5 MHz
▲ PLL/FLL clock selection	FLL clock	
Clock frequency [MHz]	0.0	Warning: The PLL/FLL clock value is 0 - the clock is disabled.

Figure 26: PEX Clock Configuration 2

6.1.3 PEX CPU Component Methods

By default, the BSP uses two methods generated by PEX. The first method **CPU_SetOperationMode** is used by the LPM driver to change low-power operating modes. The second method **CPU_MCGAutoTrim** is used to trim the internal reference clock. In this example, PEX generates both methods.

11. Click the **Methods** tab at the top of the Component Inspector.
12. Generate Code for the **SetOperationMode** method. Note that this is only required if using the LPM driver for low-power modes and the macro **MQX_ENABLE_LOW_POWER** is set. By default, this macro is not set, and the libraries should build without the **SetOperationMode** method generated.

13. Generate Code for the **MCGAutoTrim** method. Note that this method requires a clock configuration to have the Peripheral Bus Clock set in the range of 8-16 MHz and derived from an external clock source. In this example, Clock Configuration 1 was created to meet these requirements in the previous steps. If this method is not desired, remove the call to **_bsp_osc_autotrim()** in **_bsp_pre_init()** in **\mqx\source\bsp\CustomBSP\init_bsp.c**.

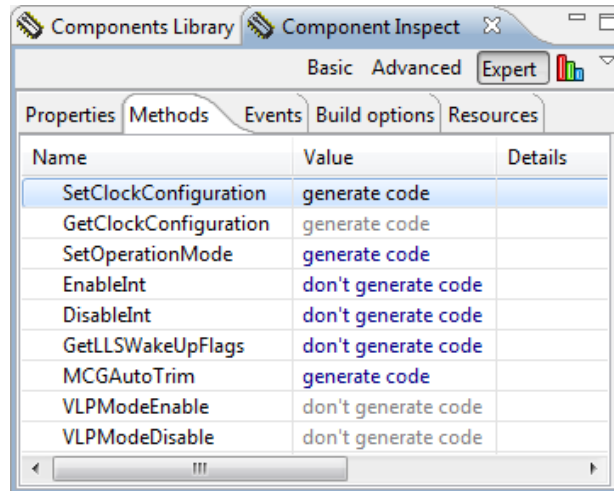


Figure 27: PEx Methods for CPU Component

6.1.4 Generate PEx Code

14. Clean up any errors in other PEx components if needed. If the PWM component is still included, change the counter frequency to 48 MHz to eliminate those errors.
15. Generate the PEx code.

6.2 Changing Clock Configuration without PEx

If PEx is not used in the BSP, the source files with the clock configuration need to be modified manually. PEx can still be used for this, even if PEx is not included in the BSP project. PEx can be used to create a new project, configure the clocks as desired, and then the generated source code can be copied from PEx into the MQX source files. Alternatively, the files below can be modified manually without PEx.

1. **bsp_cm.c**: modify the functions with the prefix **CPU_** and **__bsp_initialize_hardware()** (called **__pe_initialize_hardware()** by PEx in Cpu.c) in **bsp_cm.c**. This requires modifying the MCG peripheral registers for the desired clock configurations. See a device reference manual and the *Kinetis Quick Reference User Guide* (document KQRUG) in Chapter 4 for help on configuring the MCG.
2. **bsp_cm.h**: the macros with the prefix **CPU_** need to be modified with the values for the desired clock configurations (these come from CPU.h from PEx).
3. **bsp_cm.h**: the enumeration **BSP_CLOCK_CONFIGURATION** needs to be updated with the desired clock configurations. In this example, **BSP_CLOCK_CONFIGURATION_96MHZ** is renamed to **BSP_CLOCK_CONFIGURATION_48MHZ**. All references to this name in the BSP project need to be updated. There is only one reference in **\mqx\source\bsp\CustomBSP\CustomBSP.h**.

7 BSP include files

The following header files in `\mqx\source\bsp\CustomBSP` are modified.

7.1 <Board_Name>.h File

In this example, this file is `\mqx\source\bsp\CustomBSP\CustomBSP.h`.

7.1.1 Board Type

CustomBSP.h file includes a Board Type definition, in this case **BSP_TWR_K60D100M**. This macro is used for hardware specific code in the drivers and BSP startup code, similar to the MCU derivative macro.

1. Search the BSP library projects for this Board Type macro to see where it is used. Those files may need to be modified if this macro is changed. In this case, **BSP_TWR_K60D100M** is only referenced in one file, `\mqx\source\io\enet\macnet\macnet_1588.c`, which is used for initializing the Ethernet MAC, which will not be used in the K40 CustomBSP.
2. Change the Board Type macro to a new name for the customized BSP, in this case **BSP_CUSTOMBSP**.

7.1.2 MCU Memory Map

3. Review the memory map symbols and change as needed for the specific MCU derivative and board.
4. In this case, the program flash size and the internal SRAM in the K40 derivative is half the size of the K60 derivative in the original BSP. These lines are modified to account for the changes in flash and SRAM size:

```
#define BSP_INTERNAL_FLASH_SIZE    0x00040000
#define __FLASHX_START_ADDR        0x00030000
#define __FLASHX_END_ADDR          0x00040000
#define __VECTOR_TABLE_RAM_START   0x1FFF8000
```

5. The K40 derivative in this example includes FlexMemory, which is not in the K60 derivative from the original BSP. The macros are added to this file to define the FlexMemory address range

Within the section for the Keil compiler inside the `#ifdef __CC_ARM`:

```
#define __INTERNAL_FLEXNVM_BASE     0x10000000
#define __INTERNAL_FLEXNVM_SIZE    0x00040000
#define __INTERNAL_FLEXRAM_BASE     0x14000000
#define __INTERNAL_FLEXRAM_SIZE     0x00001000
```

6. Within the else section for all other tool chains:

```
extern uchar __INTERNAL_FLEXRAM_BASE[];
extern uchar __INTERNAL_FLEXRAM_SIZE[];
```

7. Outside that section for all tool chains:

```
#define BSP_INTERNAL_FLEXRAM_BASE ((pointer) __INTERNAL_FLEXRAM_BASE)
#define BSP_INTERNAL_FLEXRAM_SIZE ((mem_size) __INTERNAL_FLEXRAM_SIZE)
#define BSP_INTERNAL_FLEXRAM_BASE_ADDRESS 0x14000000
```

7.1.3 Clock Configuration Changes

See Section 6 [Clock Configuration](#) for changes done in previous steps.

7.1.4 GPIO Board Specifications

8. This file defines several macros specifying which GPIO pins are used for the features on the board, including the LEDs, and input switches. In this example, these lines are modified for the GPIO signals used on the TWR-K40D100M board:

```
#define BSP_LED1 (GPIO_PORT_C | GPIO_PIN7)
#define BSP_LED2 (GPIO_PORT_C | GPIO_PIN8)
#define BSP_LED3 (GPIO_PORT_C | GPIO_PIN9)
#define BSP_LED4 (GPIO_PORT_B | GPIO_PIN11)

#define BSP_SW1 (GPIO_PORT_C | GPIO_PIN5)
#define BSP_SW2 (GPIO_PORT_C | GPIO_PIN13)
#define BSP_ACCEL_IRQ (GPIO_PORT_C | GPIO_PIN12) /* onboard accel. IRQ pin */

#define BSP_LED1_MUX_GPIO (LWGPIO_MUX_C7_GPIO)
#define BSP_LED2_MUX_GPIO (LWGPIO_MUX_C8_GPIO)
#define BSP_LED3_MUX_GPIO (LWGPIO_MUX_C9_GPIO)
#define BSP_LED4_MUX_GPIO (LWGPIO_MUX_B11_GPIO)
#define BSP_SW1_MUX_GPIO (LWGPIO_MUX_C5_GPIO)
#define BSP_SW2_MUX_GPIO (LWGPIO_MUX_C13_GPIO)
#define BSP_ACCEL_MUX_GPIO (LWGPIO_MUX_C12_GPIO)

#define BSP_LCD_NAVSW_N (GPIO_PORT_C | GPIO_PIN18)
#define BSP_LCD_NAVSW_W (GPIO_PORT_A | GPIO_PIN16) /* open J4 1-2 */
#define BSP_LCD_NAVSW_E (GPIO_PORT_E | GPIO_PIN5)
#define BSP_LCD_NAVSW_S (GPIO_PORT_C | GPIO_PIN19)
#define BSP_LCD_NAVSW_CTR (GPIO_PORT_E | GPIO_PIN27)
#define BSP_LCD_DC (GPIO_PORT_A | GPIO_PIN9) /* open J14 15-16 */
#define BSP_LCD_DC_FN 1 /* LCD DC pin */
#define BSP_LCD_TCHRES_X_PLUS (GPIO_PORT_B | GPIO_PIN3) /* open J7 7-8 */
#define BSP_LCD_TCHRES_X_MINUS (GPIO_PORT_B | GPIO_PIN1) /* open J7 5-6 */
#define BSP_LCD_TCHRES_Y_PLUS (GPIO_PORT_B | GPIO_PIN0) /* open J7 3-4 */
#define BSP_LCD_TCHRES_Y_MINUS (GPIO_PORT_B | GPIO_PIN2) /* open J7 7-8 */
#define BSP_LCD_SPI_CHANNEL "spi0:"
#define BSP_LCD_X_PLUS_ADC_CHANNEL (ADC0_SOURCE_AD13)
#define BSP_LCD_Y_PLUS_ADC_CHANNEL (ADC0_SOURCE_AD8)
#define BSP_TCHRES_ADC_DEVICE "adc0:"
#define BSP_TCHRES_X_TRIGGER ADC_PDB_TRIGGER
#define BSP_TCHRES_Y_TRIGGER ADC_PDB_TRIGGER
```

7.1.5 I/O Driver Default Options

Many of the drivers use macros defined in this file for the default options. These options should all be reviewed when customizing the BSP. These steps include some key changes for this example:

9. Ethernet Driver Options. The K40 does not include the Ethernet MAC like the K60 used in the original BSP. The line below is changed to remove the ENET driver from the BSP. Also, all other macros with the text “ENET”, “MACNET”, “BSPCFG_RX”, “BSPCFG_TX” are removed.

```
#define BSP_ENET_DEVICE_COUNT 0
```

10. The SD Card detect pin is changed using the lines below. The Write Protect pin remains the same.

```
#define BSP_SDCARD_GPIO_DETECT (GPIO_PORT_A | GPIO_PIN16)
#define BSP_SDCARD_DETECT_MUX_GPIO (LWGPIO_MUX_A16_GPIO)
```

11. ADC channel for ADC example. The TWR-K40D100M board has a potentiometer on the board for evaluating the ADC. The schematic shows the potentiometer is connected to the signal ADC1_DM1. The K40 Reference Manual includes an ADC section in the Chip Configuration Chapter 3. The table for ADC1 Channel Assignment shows that for a single-ended ADC conversion on signal ADC1_DM1, the ADC1 should be set to use channel AD20. Therefore, the BSP uses the macro below. This does not need to change from the K60 BSP.

```
#define BSP_ADC_CH_POT (ADC1_SOURCE_AD20)
```

12. FlexNVM example. To enable the FlexNVM example for this BSP, these lines are added:

```
#define BSP_EE_DATA_SIZE_CODE (FLEXNVM_EE_SPLIT_1_1 | FLEXNVM_EE_SIZE_4096)
#define BSP_FLEXNVM_PART_CODE (FLEXNVM_PART_CODE_DATA128_EE128)
```

13. Segment LCD Driver. This macro is added to the file to enable the Segment LCD driver for the K40:

```
#ifndef BSPCFG_ENABLE_LCD
#define BSPCFG_ENABLE_LCD 1
#endif
```

7.1.6 Default MQX Initialization

When MQX is initialized, it uses some default settings that are including in **<Board_Name>.h** file.

14. Default I/O Channel. This defines which driver is used for the default I/O (**printf()**). In this example, the lines below are modified to use UART0 with the TTYA driver.

```
#if BSPCFG_ENABLE_TTYA
#define BSP_DEFAULT_IO_CHANNEL "ttya:" /* OSJTAG-COM polled mode */
```

7.2 BSP.h

This file includes header files needed for the drivers and BSP functions and public declarations used by the application. It should be modified for different driver support.

1. Remove header includes and declarations not used in the customize BSP. In this example, the Ethernet driver is not used, and the lines below are removed:

```
//#include <enet.h>
//#include <macnet_mk60.h>
//_mqx_int _bsp_enet_io_init(_mqx_uint);
//boolean _bsp_get_mac_address(uint_32,uint_32,_enet_address);
```

2. Modify derivative specific header files as needed. In this example, the K40 derivative includes FlexMemory while the original K60 did not. The line is modified to use the K40 header file which includes macros for the FlexNVM.

```
#include <flash_mk40.h>
```

3. Add includes and function prototypes for added drivers. In this example, the K40 BSP adds the Segment LCD driver by adding these lines:

```
#include <lcd_twrk40d100m.h>
_mqx_int _bsp_lcd_io_init( void );
```

7.3 user_config.h

This is the master configuration file for the MQX libraries. This file should be reviewed and customized for the board and application. Some key specifics include:

1. The macro MQX_CPU should be updated for the derivative used in the BSP, see [Specify MCU derivative in MQX](#) for more details. In this example the change below is made:

```
#define MQX_CPU PSP_CPU_MK40DX256
```

2. The drivers enabled by default should be changed according to the board and application. In this example, these lines are changed due to the board differences:

```
#define BSPCFG_ENABLE_TTYA      1
#define BSPCFG_ENABLE_TTYF      0
#define BSPCFG_ENABLE_I2C0      0
#define BSPCFG_ENABLE_II2C0     0
#define BSPCFG_ENABLE_I2C1      1
#define BSPCFG_ENABLE_II2C1     1
```

3. Add new drivers. Any drivers that are added to the BSP and should be enabled by default can be added to this file. In this example, the LCD driver is added and enabled with the line:

```
#define BSPCFG_ENABLE_LCD      1
```

4. Update RTCS configuration. In this example, the RTCS is not used and these lines are removed:

```
//#define RTCSCFG_ENABLE_ICMP    1
//#define RTCSCFG_ENABLE_UDP     1
//#define RTCSCFG_ENABLE_STATS   1
//#define RTCSCFG_ENABLE_GATEWAYS 1
//#define FTPDCFG_USES_MFS       1
//#define RTCSCFG_ENABLE_SNMP    0
//#define TELNETDCFG_NOWAIT      FALSE
//#define HTTPDCFG_POLL_MODE     0
//#define HTTPDCFG_STATIC_TASKS  0
//#define HTTPDCFG_DYNAMIC_TASKS 1
```

8 BSP Initialization files

The BSP is customized by several source files located in `\mqx\source\bsp\CustomBSP`. The files in this section initialize the hardware and drivers.

8.1 init_bsp.c

This file is responsible for initializing the BSP including initializing the drivers that are enabled by default in the BSP.

8.1.1 _bsp_init()

1. Changes that are needed when drivers need to be added to get initialized. In this example, the LCD driver initialization is added with the lines:

```
/* Install the LCD driver */
#if BSPCFG_ENABLE_LCD
    _bsp_lcd_io_init();
#endif
```

8.2 init_HW.c

This file has the hardware initialization needed before the kernel is initialized. **init_hardware()** in this file is called by the PSP before starting MQX. If external memory is required for the kernel, it is usually initialized in this file.

1. Modify FlexBus setup. In **_bsp_flexbus_setup()**, make the changes needed by the board and application. In this example, the FlexBus pins and initialization are changed like this:

```
pctl = (PORT_MemMapPtr)PORTE_BASE_PTR;
pctl->PCR[6] = PORT_PCR_MUX(ALT5); /* FB_ALE */
pctl->PCR[7] = PORT_PCR_MUX(ALT5); /* FB_CS0_b */
pctl->PCR[8] = PORT_PCR_MUX(ALT5); /* FB_AD4 */
pctl->PCR[9] = PORT_PCR_MUX(ALT5); /* FB_AD3 */
pctl->PCR[10] = PORT_PCR_MUX(ALT5); /* FB_AD2 */
```

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```

pctl->PCR[11] = PORT_PCR_MUX(ALT5); /* FB_AD1 */
pctl->PCR[12] = PORT_PCR_MUX(ALT5); /* FB_AD0 */

pctl = (PORT_MemMapPtr)PORTA_BASE_PTR;
pctl->PCR[6] = PORT_PCR_MUX(ALT5); /* FB_CLKOUT */
pctl->PCR[7] = PORT_PCR_MUX(ALT5); /* FB_AD18 */
pctl->PCR[8] = PORT_PCR_MUX(ALT5); /* FB_AD17 */
pctl->PCR[9] = PORT_PCR_MUX(ALT5); /* FB_AD16 */
pctl->PCR[10] = PORT_PCR_MUX(ALT5); /* FB_AD15 */
pctl->PCR[11] = PORT_PCR_MUX(ALT5); /* FB_OE_b */
pctl->PCR[24] = PORT_PCR_MUX(ALT5); /* FB_AD14 */
pctl->PCR[25] = PORT_PCR_MUX(ALT5); /* FB_AD13 */
pctl->PCR[26] = PORT_PCR_MUX(ALT5); /* FB_AD12 */
pctl->PCR[27] = PORT_PCR_MUX(ALT5); /* FB_AD11 */
pctl->PCR[28] = PORT_PCR_MUX(ALT5); /* FB_AD10 */
pctl->PCR[29] = PORT_PCR_MUX(ALT5); /* FB_AD19 */

pctl = (PORT_MemMapPtr)PORTD_BASE_PTR;
pctl->PCR[10] = PORT_PCR_MUX(ALT5); /* FB_AD9 */
pctl->PCR[11] = PORT_PCR_MUX(ALT5); /* FB_AD8 */
pctl->PCR[12] = PORT_PCR_MUX(ALT5); /* FB_AD7 */
pctl->PCR[13] = PORT_PCR_MUX(ALT5); /* FB_AD6 */
pctl->PCR[14] = PORT_PCR_MUX(ALT5); /* FB_AD5 */
pctl->PCR[15] = PORT_PCR_MUX(ALT5); /* FB_RW_b */

```

2. To use the MRAM on the TWR-MEM board, the FlexBus setup in **_bsp_flexbus_mram_setup()** is changed to:

```

fb_ptr->CS[0].CSAR = base_address;
/* CS0 control (8bit data, 1 wait state, multiplexed mode) */
fb_ptr->CS[0].CSCR = FB_CSCR_ASET(1) |
                    FB_CSCR_AA_MASK |
                    FB_CSCR_WS(2) |
                    FB_CSCR_PS(1) |
                    FB_CSCR_BEM_MASK |
                    FB_CSCR_BLS_MASK;

/* CS0 address mask and enable */
fb_ptr->CS[0].CSMR = FB_CSMR_BAM(0x07) | FB_CSMR_V_MASK;

```

3. To use the address latch on the TWR-K40D100M board, the lmgpio driver is added to **_bsp_flexbus_lcd_setup()** for the address latch. **_bsp_flexbus_lcd_setup()** is changed to the lines:

```

void _bsp_flexbus_lcd_setup (const uint_32 base_address)
{
    FB_MemMapPtr fb_ptr = FB_BASE_PTR;
    LWGPIO_STRUCT ale_pin;

    /* Enable external LCD mapped on CS0 */
    fb_ptr->CS[0].CSAR = base_address;
    fb_ptr->CS[0].CSCR = FB_CSCR_BLS_MASK |
                        FB_CSCR_AA_MASK |
                        FB_CSCR_PS(2) |
                        FB_CSCR_BEM_MASK;

    /*
     * The address range is set to 128K because
     * the DC signal is connected on address wire
     */
    fb_ptr->CS[0].CSMR = FB_CSMR_BAM(1) | FB_CSMR_V_MASK;

    lmgpio_init(&ale_pin, GPIO_PORT_E | GPIO_PIN6, LWGPIO_DIR_NOCHANGE,
LWGPIO_VALUE_NOCHANGE);
    lmgpio_set_direction(&ale_pin, LWGPIO_DIR_OUTPUT);
    lmgpio_set_value(&ale_pin, LWGPIO_VALUE_HIGH);
    lmgpio_set_functionality(&ale_pin, 1);
}

```

4. To use the pccard driver, the FlexBus setup in **_bsp_flexbus_pccard_setup()** is changed to:

```

fb_ptr->CS[0].CSMR = 0;

/* Enable external PCCARD mapped on CS0 */
fb_ptr->CS[0].CSAR = base_address;
/* CS0 control (8bit data, 5 waitstates, multiplexed mode) */
fb_ptr->CS[0].CSCR = FB_CSCR_ASET(1) |
                    FB_CSCR_AA_MASK |
                    FB_CSCR_WS(11) |
                    FB_CSCR_PS(1) |
                    FB_CSCR_BEM_MASK |
                    FB_CSCR_BLS_MASK;

/* CS0 address mask (64 KB) and enable */
fb_ptr->CS[0].CSMR = FB_CSMR_BAM(0) | FB_CSMR_V_MASK;

```

5. Modify **init_hardware()** for the desired setup of the BSP. In this example, the 256 KB flash device is not impacted by erratum e2647, so this workaround is removed. These lines are removed:

```

//if (((SIM_SDID & SIM_SDID_REVID_MASK) >> SIM_SDID_REVID_SHIFT) == 0)
//{
//    FMC_PFB0CR &= ~(FMC_PFB0CR_B0DCE_MASK | FMC_PFB0CR_B0ICE_MASK | FMC_PFB0CR_B0SEBE_MASK);
//    FMC_PFB1CR &= ~(FMC_PFB1CR_B1DCE_MASK | FMC_PFB1CR_B1ICE_MASK | FMC_PFB1CR_B1SEBE_MASK);
//}

```

8.3 init_GPIO.c

This file controls the pin setup for the device, including the pin muxing options for the driver signals.

1. In **_bsp_serial_io_init()**, the pins for UART4 are changed using the code:

```

case 4:
    pctl = (PORT_MemMapPtr)PORTC_BASE_PTR;
    if (flags & IO_PERIPHERAL_PIN_MUX_ENABLE)
    {
        /* PTC14 as RX function (Alt.3) + drive strength */
        pctl->PCR[14] = 0 | PORT_PCR_MUX(3) | PORT_PCR_DSE_MASK;
        /* PTC15 as TX function (Alt.3) + drive strength */
        pctl->PCR[15] = 0 | PORT_PCR_MUX(3) | PORT_PCR_DSE_MASK;
    }
    if (flags & IO_PERIPHERAL_PIN_MUX_DISABLE)
    {
        /* PTC14 default */
        pctl->PCR[14] = 0;
        /* PTC15 default */
        pctl->PCR[15] = 0;
    }
}

```

2. In **_bsp_adc_channel_io_init()**, the arrays **adcX_conv_table[]** should be updated if the ADC channels available are different. In this example, there are no changes needed.
3. In **_bsp_i2c_io_init()**, the pins for the I2C0 are changed using the code:

```

case 0:
    /* configure GPIO for I2C0 peripheral function */
    pctl = (PORT_MemMapPtr)PORTB_BASE_PTR;

    pctl->PCR[2] = PORT_PCR_MUX(ALT2) | PORT_PCR_ODE_MASK;
    pctl->PCR[3] = PORT_PCR_MUX(ALT2) | PORT_PCR_ODE_MASK;

```

4. **_bsp_enet_io_init()** is removed since the derivative in this example does not include the Ethernet MAC, and the ENET driver is removed from the BSP.

5. In **_bsp_usb_io_init()**, the USB clock divider for 48 MHz is changed because the PLL output was changed from 96 MHz to 48 MHz. The **SIM_CLKDIV2** register is changed using the code:

```
SIM_CLKDIV2 = 0; /* Update USB clock prescalers */
```

6. In **_bsp_usb_io_init()**, the GPIO pin to enable the USB power on the TWR-SER2 board is changed using the code:

```
#if BSP_USB_TWR_SER2
/* TWR-SER2 board has 2 connectors: on channel A, there is Micro-USB connector,
** which is not routed to TWRK40 board. On channel B, there is standard
** A-type host connector routed to the USB0 peripheral on TWRK40. To enable
** power to this connector, GPIO PB9 must be set as GPIO output
*/
PORT_PCR_REG(PORTB_BASE_PTR, 9) = PORT_PCR_MUX(0x01) | PORT_PCR_PE_MASK;
GPIO_PDDR_REG(PTB_BASE_PTR) |= 1 << 9; // PB9 as output
GPIO_PDOR_REG(PTB_BASE_PTR) |= 1 << 9; // PB9 in high level
#endif
```

7. In **_bsp_serial_rts_init()**, the RTS option for UART4 is removed by deleting the lines:

```
//      case 4:
//          pctl = (PORT_MemMapPtr)PORTE_BASE_PTR;
//          pctl->PCR[27] = 0 | PORT_PCR_MUX(3);
//          break;
```

8. The LCD pin initialization is added, by adding **_bsp_lcd_io_init()**:

```
/*FUNCTION*-----
*
* Function Name      : _bsp_lcd_io_init
* Returned Value     : 0 for success, -1 for failure
* Comments          :
*   This function performs BSP-specific initialization related to LCD
*
*END*-----*/
_mqx_int _bsp_lcd_io_init
(
    void
)
{
    #define ALT7 7

    PORT_MemMapPtr pctl;

    /* enable clock to lcd module */
    SIM_SCGC3 |= SIM_SCGC3_SLCD_MASK;

    /* set gpio pin functionality to LCD */
    pctl = (PORT_MemMapPtr)PORTB_BASE_PTR;

    pctl->PCR[0] = PORT_PCR_MUX(ALT7); /* COM1 */
    pctl->PCR[1] = PORT_PCR_MUX(ALT7); /* COM2 */
    pctl->PCR[2] = PORT_PCR_MUX(ALT7); /* COM3 */
    pctl->PCR[3] = PORT_PCR_MUX(ALT7); /* COM4 */

    pctl->PCR[16] = PORT_PCR_MUX(ALT7); /* pin8 */
    pctl->PCR[17] = PORT_PCR_MUX(ALT7); /* pin9 */
    pctl->PCR[18] = PORT_PCR_MUX(ALT7); /* pin10 */
    pctl->PCR[19] = PORT_PCR_MUX(ALT7); /* pin11 */

    pctl = (PORT_MemMapPtr)PORTC_BASE_PTR;

    pctl->PCR[0] = PORT_PCR_MUX(ALT7); /* pin5 */
    pctl->PCR[1] = PORT_PCR_MUX(ALT7); /* pin6 */
    pctl->PCR[2] = PORT_PCR_MUX(ALT7); /* pin7 */

    return MQX_OK;
}
```

9. In `_bsp_sai_io_init()`, the pins for I2S0 are changed with these lines:

```
/* Enable SSI pins */
PORTA_PCR17 |= PORT_PCR_MUX(0x06);          /* Configure port for MCLK output */

/* GPIO for SSI0_BCLK */
PORTA_PCR5 |= PORT_PCR_MUX(0x06);           /* Configure Port for TX Bit Clock */

/* GPIO for SSI0_FS */
PORTA_PCR13 |= PORT_PCR_MUX(0x06);          /* Configure port for TX Frame Sync */

/* GPIO for SSI0_XD */
PORTA_PCR12 |= PORT_PCR_MUX(0x06);          /* Configure port for TX Data */
PORTA_PCR15 |= PORT_PCR_MUX(0x06);          /* Configure port for RX Data */
```

8.4 bsp_cm.c

Changes to this file are covered in Section [6 Clock Configuration](#).

9 BSP Driver Changes

While the driver sources files in `\mqx\source\io` are common across different BSPs, the BSP customizes the drivers using files in `\mqx\source\bsp\CustomBSP`. All files in this directory should be reviewed and modified as needed for the board and application.

9.1 init_enet.c

In this example using the K40, there is no Ethernet MAC available on the MCU and no need for the ENET driver. The file `init_enet.c` is removed from the BSP.

9.2 init_flashx.c

In this example, the MCU derivative in the original BSP did not include the FlexMemory feature, but the derivative in the custom BSP does. This file is modified to change the FlashX driver parameters to support the FlexMemory. Refer to the FlashX Driver chapter in the [MQX™ I/O Drivers User Guide](#) for more details on the FlashX driver. In this example, the structure and array are changed to this code:

```
const FLASHX_FILE_BLOCK _bsp_flashx_file_blocks[] = {
    { "bank0", BSP_INTERNAL_FLASH_BASE, BSP_INTERNAL_FLASH_SIZE - 1 },
    { "flexram0", (_mem_size) BSP_INTERNAL_FLEXRAM_BASE, BSP_INTERNAL_FLEXRAM_BASE_ADDRESS +
    BSP_INTERNAL_FLEXRAM_SIZE - 1 },
    { "", (_mem_size) __FLASHX_START_ADDR, (uint_32) __FLASHX_END_ADDR },
    { NULL, 0, 0 }
};

const FLASHX_INIT_STRUCT _bsp_flashx_init = {
    0x00000000, /* BASE_ADDR should be 0 for internal flashes */
    _flashx_kinetisX_block_map, /* HW block map for KinetisX devices */
    _bsp_flashx_file_blocks, /* Files on the device defined by the BSP */
    &flashx_ftfl_if, /* Interface for low level driver */
    32, /* For external devices, data lines for the flash. Not used for internal flash
    devices. */
    1, /* Number of parallel external flash devices. Not used for internal flash devices. */
    0, /* 0 if the write verify is requested, non-zero otherwise */
    NULL /* low level driver specific data */
};
```

9.3 init_SAI.c

In this example, the Tx channel for the SAI driver is changed using the structure:

```
KSAI_INIT_STRUCT _bsp_ksai_init = {
    0, /* Selected peripheral (HW channel) */
    0, /* TX channel */
    0, /* RX channel */
    I2S_TX_ASYNCHRONOUS | /* TX is asynchronous */
    I2S_RX_SYNCHRONOUS | /* RX hooked on TX */
    I2S_TX_BCLK_NORMAL | /* Both TX and RX are clocked by the transmitter */
    I2S_TX_BCLK_NORMAL, /* bit clock (SAI_TX_BCLK) */
    I2S_TX_MASTER | /* SAI transmitter mode */
    I2S_RX_MASTER, /* SAI receiver mode */
    16, /* Data bits */
    I2S_CLK_INT, /* Clock source */
    FALSE, /* Tx Dummy */
    5, /* Interrupt priority */
    512, /* Buffer size */
    CM_CLOCK_SOURCE_SYSTEM, /* Internal master clock source */
    &bsp_audio_data_init /* Audio init */
};
```

9.4 init_SCI.c

Because the UARTs used on this board have changed, this file is changed for the low-power settings used by the serial driver. These low-power settings are used with the Low-Power Manager (LPM) driver. For more details on the LPM, see the [Application Note Freescale MQX Low-Power Management \(document AN4447\)](#). In this example, the low-power operation modes for SCI0 and SCI5 are changed using the code:

```
const KUART_OPERATION_MODE_STRUCT _bsp_sci0_operation_modes[LPM_OPERATION_MODES] =
{
    /* LPM_OPERATION_MODE_RUN */
    {
        IO_PERIPHERAL_PIN_MUX_ENABLE | IO_PERIPHERAL_CLOCK_ENABLE |
        IO_PERIPHERAL_MODULE_ENABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_WAIT */
    {
        IO_PERIPHERAL_PIN_MUX_ENABLE | IO_PERIPHERAL_CLOCK_ENABLE |
        IO_PERIPHERAL_MODULE_ENABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_SLEEP */
    {
        IO_PERIPHERAL_PIN_MUX_ENABLE | IO_PERIPHERAL_CLOCK_ENABLE |
        IO_PERIPHERAL_MODULE_ENABLE | IO_PERIPHERAL_WAKEUP_ENABLE |
        IO_PERIPHERAL_WAKEUP_SLEEPONEXIT_DISABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_STOP */
    {
        IO_PERIPHERAL_PIN_MUX_DISABLE | IO_PERIPHERAL_CLOCK_DISABLE,
        0,
        0,
        0
    }
};
```

```

const KUART_OPERATION_MODE_STRUCT _bsp_sci5_operation_modes[LPM_OPERATION_MODES] =
{
    /* LPM_OPERATION_MODE_RUN */
    {
        IO_PERIPHERAL_PIN_MUX_DISABLE | IO_PERIPHERAL_CLOCK_DISABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_WAIT */
    {
        IO_PERIPHERAL_PIN_MUX_DISABLE | IO_PERIPHERAL_CLOCK_DISABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_SLEEP */
    {
        IO_PERIPHERAL_PIN_MUX_DISABLE | IO_PERIPHERAL_CLOCK_DISABLE,
        0,
        0,
        0
    },

    /* LPM_OPERATION_MODE_STOP */
    {
        IO_PERIPHERAL_PIN_MUX_DISABLE | IO_PERIPHERAL_CLOCK_DISABLE,
        0,
        0,
        0
    }
};

```

9.5 Remove Driver Source files from BSP Project

In this example, the ENET driver files are removed from the BSP project. This includes all the source files in `/mqx/source/io/enet` and any subdirectories.

9.6 Add Driver source files to BSP

In this example, the derivative is changed from a K60 to a K40, which adds the Segment LCD peripheral to the Kinetis device. MQX already includes a Segment LCD driver including files for the small LCD included with the TWR-K40D100M board. This section describes how to add this driver to the custom BSP.

1. Add driver source files to BSP. In this example, the source file is already included in the MQX release, and located at `\mqx\source\io\lcd\lcd_twrk40d100m.c`. See the tool chain documentation and add this file to the BSP project.
2. Add driver path to compiler settings. The path needs to be added to each library project so the compiler can find the driver header files. See the toolchain and add the path `\mqx\source\io\lcd` to all MQX library projects.
3. Modify BSP initialization code to add driver. This was done previously when modifying `init_bsp.c` in `_bsp_init()`.
4. Modify `user_config.h` to include driver in BSP. This was done previously when modifying `user_config.h` in `user_config.h`.

10 BSP Memory Map and Linker files

The BSP macros related to the memory map were previously changed in **CustomBSP.h** file in [MCU Memory Map](#). In addition, the memory map in the linker files may need to be changed. In this example, the original Kinetis K60 has more program flash and RAM, but the K40 in the custom BSP adds FlexMemory. See Table 1 for the difference in sizes of the memory map.

Table 1: Memory Map Size Differences between Derivatives

Part Number	MK60DN512VMD10	MK40DX256VMD10
Program Flash	512KB	256KB
System SRAM	128KB	64KB
FlexNVM	0KB	256KB
FlexRAM	4KB	4KB

10.1 CodeWarrior GCC Linker File

The linker file is located with the BSP files in `\mqx\source\bsp\CustomBSP\gcc_cw\intflash.ld`. Modify the memory map. In this example, the following lines are changed to this code:

```
MEMORY
{
    vectorrom      (RX): ORIGIN = 0x00000000, LENGTH = 0x00000400
    cfmprotrom     (R): ORIGIN = 0x00000400, LENGTH = 0x00000020
    rom            (RX): ORIGIN = 0x00000420, LENGTH = 0x0003FBE0 /* Code + Const data */
    ram            (RW): ORIGIN = 0x1FFF8000, LENGTH = 0x00010000 /* SRAM - RW data */

    /* kernel space starts after RAM variables (Location of MQX Kernel data + MQX heap) */
    end_of_kd      (RW): ORIGIN = 0x20007FF0, LENGTH = 0x00000000

    /* Boot stack reused by MQX Kernel data */
    bstack         (RW): ORIGIN = 0x20007A00, LENGTH = 0x00000200 /* Boot stack */
    end_bstack     (RW): ORIGIN = 0x20007C00, LENGTH = 0x00000000 /* Boot stack end address
requires 4B alignment */
}

SECTIONS
{
    __INTERNAL_SRAM_BASE = 0x1FFF8000;
    __INTERNAL_SRAM_SIZE = 0x00010000;

    __INTERNAL_FLASH_BASE = 0x00000000;
    __INTERNAL_FLASH_SIZE = 0x00040000;

    __INTERNAL_FLEXNVM_BASE = 0x10000000;
    __INTERNAL_FLEXNVM_SIZE = 0x00040000;
    __INTERNAL_FLEXRAM_BASE = 0x14000000;
    __INTERNAL_FLEXRAM_SIZE = 0x00001000;
```

10.2 CodeWarrior Freescale Linker File

This toolchain option has two linker files, one for internal flash and the other for internal RAM. They are located with the BSP files in:

- Internal Flash: `\mqx\source\bsp\CustomBSP\cw\intflash.lcf`
- Internal RAM: `\mqx\source\bsp\CustomBSP\cw\intram.lcf`

1. Modify the internal flash linker file memory map. In this example, these lines are changed to this code:

```
MEMORY
{
    vectorrom      (RX): ORIGIN = 0x00000000, LENGTH = 0x00000400
    cfmprotrom     (RX): ORIGIN = 0x00000400, LENGTH = 0x00000020
    rom            (RX): ORIGIN = 0x00000420, LENGTH = 0x0003FB00    # Code + Const data
    ram            (RW): ORIGIN = 0x1FFF8000, LENGTH = 0x00010000    # SRAM - RW data

    # kernel space starts after RAM variables (Location of MQX Kernel data + MQX heap)
    end_of_kd      (RW): ORIGIN = 0x20007FF0, LENGTH = 0x00000000

    # Boot stack reused by MQX Kernel data
    bstack        (RW): ORIGIN = 0x20007A00, LENGTH = 0x00000200    # Boot stack
    end_bstack     (RW): ORIGIN = 0x20007C00, LENGTH = 0x00000000
}

KEEP_SECTION { .vectors_rom, .vectors_ram, .cfmconfig }

SECTIONS
{
    __INTERNAL_SRAM_BASE = 0x1FFF8000;
    __INTERNAL_SRAM_SIZE = 0x00010000;
    __INTERNAL_FLASH_BASE = 0x00000000;
    __INTERNAL_FLASH_SIZE = 0x00040000;
    __INTERNAL_FLEXPVM_BASE = 0x10000000;
    __INTERNAL_FLEXPVM_SIZE = 0x00040000;
    __INTERNAL_FLEXPVM_RAM_BASE = 0x14000000;
    __INTERNAL_FLEXPVM_RAM_SIZE = 0x00001000;
}
```

2. Modify the internal RAM linker file memory map. In this example, these lines are changed to this code:

```
MEMORY
{
    vectorram      (RW): ORIGIN = 0x1FFF8000, LENGTH = 0x00000420    # SRAM - Vector table
    rom            (RX): ORIGIN = 0x1FFF8420, LENGTH = 0x00007BE0    # SRAM - Code + Const data
    ram            (RW): ORIGIN = 0x20000000, LENGTH = 0x00008000    # SRAM - RW data

    # kernel space starts after RAM variables (Location of MQX Kernel data + MQX heap)
    end_of_kd      (RW): ORIGIN = 0x20007FF0, LENGTH = 0x00000000

    # Boot stack reused by MQX Kernel data
    bstack        (RW): ORIGIN = 0x20007A00, LENGTH = 0x00000200    # Boot stack
    end_bstack     (RW): ORIGIN = 0x20007C00, LENGTH = 0x00000000
}

KEEP_SECTION { .vectors_rom }

SECTIONS
{
    __INTERNAL_SRAM_BASE = 0x20000000;
    __INTERNAL_SRAM_SIZE = 0x00008000;
    __INTERNAL_FLASH_BASE = 0x00000000;
    __INTERNAL_FLASH_SIZE = 0x00040000;
    __INTERNAL_FLEXPVM_BASE = 0x10000000;
    __INTERNAL_FLEXPVM_SIZE = 0x00040000;
    __INTERNAL_FLEXPVM_RAM_BASE = 0x14000000;
    __INTERNAL_FLEXPVM_RAM_SIZE = 0x00001000;
}
```

10.3 IAR EW-ARM Linker File

This toolchain option has two linker files, one for internal flash and the other for internal RAM. They are located with the BSP files in:

- Internal Flash: `\mqx\source\bsp\CustomBSP\iar\intflash.icf`

- Internal RAM: `\mqx\source\bsp\CustomBSP\iar\ram.icf`

1. Modify the internal flash linker file memory map. In this example, these lines are changed to this code:

```
define symbol __ICFEDIT_region_ROM_end__ = 0x0003FFFF;
define symbol __ICFEDIT_region_RAM_start__ = 0x1FFF8000;
define symbol __ICFEDIT_region_RAM_end__ = 0x20007FF0;

define exported symbol __INTERNAL_FLASH_SIZE = 0x00040000;
define exported symbol __INTERNAL_FLEXNVM_BASE = 0x10000000;
define exported symbol __INTERNAL_FLEXNVM_SIZE = 0x00040000;
define exported symbol __INTERNAL_FLEXRAM_BASE = 0x14000000;
define exported symbol __INTERNAL_FLEXRAM_SIZE = 0x00001000;
```

2. Modify the internal RAM linker file memory map. In this example, these lines are changed to this code:

```
define symbol __ICFEDIT_intvec_start__ = 0x1fff8000;

define symbol __ICFEDIT_region_ROM_start__ = 0x1fff8000;

define exported symbol __INTERNAL_FLASH_SIZE = 0x00040000;

define exported symbol __INTERNAL_FLEXNVM_BASE = 0x10000000;
define exported symbol __INTERNAL_FLEXNVM_SIZE = 0x00040000;

define exported symbol __INTERNAL_FLEXRAM_BASE = 0x14000000;
define exported symbol __INTERNAL_FLEXRAM_SIZE = 0x00001000;

define exported symbol __VECTOR_TABLE_ROM_START = 0x1fff8000;
```

10.4 Keil uVision Linker File

The linker file is located with the BSP files in `\mqx\source\bsp\CustomBSP\uv4\intflash.scf`

Modify the memory map. In this example, the following lines are changed to this code:

```
#define FLASHX_SECT_SIZE 0x800
#define USERFLASH_BASE_ADDR 0x00030000

; make sure this alignment matches the alignment in kernel_data.s in the bsp
FLASHX_START MY_ALIGN(ImageLimit(CODE), FLASHX_SECT_SIZE)
{
    * (FLASHX)
}

RAM_VECTORS 0x1FFF8000 ; For ram vector table. Used when MQX_ROM_VECTORS is set to zero.
{
    vectors.o (.vectors_ram)
}

KERNEL_DATA_END 0x20007FF0 ; RAM_END
{
    * (KERNEL_DATA_END) ; end of kernel data
}

BOOT_STACK_ADDR 0x20007EF0
{
    * (BOOT_STACK)
}
```

11 Post-Link Batch Files

If using PEx, previous changes to the BSP batch file were done in [Update IAR BSP Batch File](#) or [Update Keil BSP Batch File](#).

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In this example, the ENET driver is removed and the Segment LCD driver is added. The BSP batch file is located at `\mqx\build\bat\bsp_CustomBSP.bat`

1. Remove commands for removed drivers. In this example, delete these lines:

```
copy %MQXROOTDIR%\mqx\source\io\enet\enet.h %OUTPUTDIR%\enet.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\enet_rev.h %OUTPUTDIR%\enet_rev.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\enet_wifi.h %OUTPUTDIR%\enet_wifi.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\ethernet.h %OUTPUTDIR%\ethernet.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\macnet\macnet_1588.h %OUTPUTDIR%\macnet_1588.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\macnet\macnet_mk60.h %OUTPUTDIR%\macnet_mk60.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\macnet\macnet_rev.h %OUTPUTDIR%\macnet_rev.h /Y
copy %MQXROOTDIR%\mqx\source\io\enet\phy\phy_ksz8041.h %OUTPUTDIR%\phy_ksz8041.h /Y
```

2. Add commands for added drivers. In this example, add the lines:

```
copy %MQXROOTDIR%\mqx\source\io\lcd\lcd_twrk40d100m.h %OUTPUTDIR%\lcd_twrk40d100m.h /Y
```

3. Changed commands for header file name changes. If the BSP uses different header files for derivative-specific driver details, the batch file needs to be updated to copy these files to the `\lib` folder. In this example, the lines are changed:

```
copy %MQXROOTDIR%\mqx\source\io\flashx\freescall\flash_mk40.h %OUTPUTDIR%\flash_mk40.h /Y
```

4. Update the PSP batch file if the derivative header file is changed (done previously in [Specify MCU derivative in MQX](#)). The batch file runs after the PSP project is built, and copies header files to the `\lib` folder to be used when compiling the application. The batch file must be updated to copy the different header file. In this example, modify the batch file found at `\mqx\build\bat\psp_CustomBSP.bat`:

```
copy %MQXROOTDIR%\mqx\source\psp\cortex_m\cpu\MK40D10.h %OUTPUTDIR%\MK40D10.h /Y
```

12 CodeWarrior Debugger Memory File

In this example, the file is `\mqx\source\bsp\CustomBSP\<toolchain>\dbg\CustomBSP.mem`. This is a text file, and is simple to modify manually. Another option is to use the `.MEM` file provided by CodeWarrior. Use the files located in `<CodeWarrior Installation Path>\MCU\ARM_EABI_Support\Memory_Config_Files`. For this example, these steps update the `.MEM` file:

1. Copy the `.MEM` file provided in CodeWarrior. In this example, copy the file `<CodeWarrior Installation Path>\MCU\ARM_EABI_Support\Memory_Config_Files\K40DX256M10.mem`.
2. Paste the file into the BSP and rename to the same `.MEM` file that was cloned, overwriting the cloned file. In this example, the resulting file is `\mqx\source\bsp\CustomBSP\<toolchain>\dbg\CustomBSP.mem`.

13 Porting Example Applications

Here are the steps used when testing this ported BSP example with the example applications listed in the next section:

1. Change the toolchain setting for the MCU derivative in the application example project. In CodeWarrior, the Target Type is changed in the Connection for the Debug Configuration. In this example, the MCU derivative is changed to support the part number MK40DX256VMD10.

13.1 Testing CustomBSP

The following examples were tested in this porting example, to ensure the BSP port to the TWR-K40D100M was successful:

- **flashx** - tests changes to memory map using the flashx driver. The example is located at `\mqx\examples\flashx\<toolchain>\flashx_CustomBSP`.
- **lcd** – tests Segment LCD driver added to BSP. Uses module TWRPI-SLCD that comes with TWR-K40D100M board. The example is located at `\mqx\examples\lcd\<toolchain>\lcd_CustomBSP`.
- **pe_demo** – tests PEx integration in BSP. Refer to the tutorial in the document at `\doc\tools\cw\FSL_MQX_in_CW_10_x.pdf` for details on using this demo. The demo is located at `\demo\pe_demo\<toolchain>\pe_demo_CustomBSP`.
- **lowpower** – tests using LPM driver for low-power mode and clock configuration changes. The example is located at `\mqx\examples\lowpower\<toolchain>\lowpower_CustomBSP`.
- **flexnvm** – tests memory map changes, and addition of FlexMemory to BSP. The flexnvm example uses the EEPROM feature of FlexMemory to store non-volatile data. The example is located at `\mqx\examples\flexnvm\<toolchain>\flexnvm_CustomBSP`.
- **i2s_demo** – tests different pins in SAI interface. Uses the Tower System module TWR-AUDIO-SGTL for the audio codec. NOTE: Need jumper on TWR-K40D100M pins 5-6 on J4 for this example to play audio output. The example is located at `\mqx\examples\i2s_demo\<toolchain>\i2s_demo_CustomBSP`.
- **mfs_usb** – tests USB driver, including USB clock divider change. Tested with and without PEx in the BSP. This example mounts a USB flash drive, and is located at `\mfs\examples\mfs_usb\<toolchain>\mfs_usb_CustomBSP`.

14 Conclusion

Freescal MQX is a scalable RTOS that complements Freescal's broad family of micro-controllers, including Kinetis. The provided MQX BSPs can be ported across all the supported Freescal devices using the steps outlined in the document *Freescal MQX™ RTOS BSP Porting Guide* (document MQXBSPPG), and using this document for a detailed example. For the most up-to-date MQX information and documentation, or to download MQX, visit the freescale.com/mqx.