MSP430® IEC60730 Software Package for F5xx, FR57xx, G23xx, G24xx, G25xx, G2x44, and G2x55 Devices 1.04.00.05 version

USER'S GUIDE

Copyright

Texas Instruments
Post Office Box 655303
Dallas, TX 75265
http://www.ti.com/msp430

Revision Information

This is version 1.04.00.05 of this document, last updated on 2015-02-12$_{1}$8 : 19 : 04$_$0600.

Table of Contents

1 Introduction

Manufacturers of household appliances must take steps to ensure safe and reliable operation of their products in order to meet the IEC60730 standard. The IEC60730 standard covers mechanical, electrical, electronic, EMC, and abnormal operation of AC appliances. Annex H of this standard covers the aspects most relevant to microcontrollers including the three software classifications defined for automatic electronic controls:

- Class A.- functions such as room thermostats, humidity controls, lighting controls, timers and switches. These are distinguished by not being relied upon for the safety of the equipment.
- Class B.- functions such as thermal cut-offs are intended to prevent unsafe operation of appliances such as washing machines, dishwashers, dryers, refrigerators, freezers and cookers/stoves.
- Class C.- functions are intended to prevent special hazards such as explosions. These include automatic burner controls and thermal cut-outs for closed, unvented water heaters.

These software libraries allow for a variety of system tests required by IEC 60730-1:2010 for up to Class B products. The software libraries include projects that demonstrate running power-on self-test (POST) and periodic self-test (PST) with reporting conducted through flashing an LED. The userŠs guide demonstrates how to integrate the POST and PST into an application design. In addition, the software package for IEC 60730 also includes a GUI configuration tool which allows users to easily generate customized configuration header files.

All the configurations available for the test can be found in “IEC60730_user_config.h" file. The default options for the tests are:

- ENABLED_WDT is enabled
- JUMP_TO_FAILSAFE is enabled
- MAIN_CLOCK_FREQUENCY is defined at 12 MHz
- RAM test is run using March X algorithm in non-destructive mode
- PERCENT_FREQUENCY_DRIFT is defined +/-3%
- Stack size of 80 Bytes and
- MINIMUM_ADC_COUNT_DRIFT and MAXIMUM_ADC_COUNT_DRIFT are defined as -50 and 50, resectively.
- CRC_CHECKSUM_LOCATION
  - for MSP430G2553: Information memory (0x1004)
  - for MSP430F5529: Beginning of Info D section (0x1800)
  - for MSP430FR5739: Beginning of Info A section (0x1880)

The examples for MSP430F5529 in this library use API calls from Driverlib which is part of MSP430Ware.

The following tool chains are supported:

- Texas Instruments Code Composer Studio™v5.3 or later;
- IAR Embedded Workbench®v5.51.3 or later ;

2 API relation to Table H.1 in IEC60730:2010 standard

The table below show the relation of the API provided in MSP430 IEC60730 Software Package and the component that needs to be tested according to Table H.1 in Annex H of the IEC60730:2010 standard.

Component	Test Item	Software Package API
1.1	CPU Registers	CPU test API
1.3	PC	PC test API
2.0	Interrupt handling and execution	Device project example shows a method to test interrupts in software
3.0	Clock frequency	CLOCK test API
4.1	Memory Testing (Flash\FRAM)	CRC test API
4.2	Memory Testing (RAM\FRAM)	MARCH test API
4.3	Memory addressing	N/A
5.0	Memory (external)	Does not apply to MSP430
5.2	Memory Addressing (external)	Does not apply to MSP430
6.0	Communication	N/A
6.3	Timing of communication	N/A
7.0	Input/output periphery	GPIO test APIs
7.2.1	A/D tests	ADC test API
7.2.2	Analog multiplexer	N/A
9.0	Custom chip	Does not apply to MSP430

Certain tests are not relevant to MCUs because the function is implemented by another chip external to the MCU – usually memory of a custom chip.

3 Running IEC60730 example projects

3.1 Running IEC60730 example projects

The example projects included in this library will run all available tests in addition to the interrupt test which is included in the example project. The example projects will toggle different pins depending on the result of each test. The table below shows the number of times the FAILURE pin will toggle to indicate which test failed. If none of the tests failed, the SUCCESS pin will remain set.

The example projects contain two functions calls that are not included in the software package. The two function calls are IEC60730_FAIL_SAFE_failSafe and IEC60730_INTERRUPT_TEST_testInterrupt. IEC60730_FAIL_SAFE_failSafe is a user defined function which needs to ensure that the application shuts downs gracefully. The purpose of defining this function was to show how the JUMP_TO_FAILSAFE macro can be use during the development phase of the application. In the example projects IEC60730_FAIL_SAFE_failSafe only reports the type of failure. IEC60730_INTERRUPT_TEST_testInterrupt is also a user defined function which shows how each interrupt in the device can be triggered by software and verified that the interrupt jumped to the correct Interrupt Service Routine (ISR).

Failure Detected	Number of Toggles
CPU test failure	1
PC test failure	2
OSCILLATOR test failure	3
MARCH test failure	4
CRC test failure	5
INTERRUPT test failure	6
ADC test failure	7
GPIO INPUT test failure	8
GPIO OUTPUT test failure	9

Each example project uses different pin configuration to display SUCCESS or FAILURE status of each test. The table below shows the pin configuration for each project. The table also shows the preferred development kit to run the examples.

Example Project Name	SUCCESS Pin	FAILURE Pin	Preferred Dev Kit
IEC60730_msp430g2553 _example	P1.6	P1.0	MSP430-EXP430G2
IEC60730_msp430f5529 _example	P8.2	P1.0	MSP-EXP430F5529
IEC60730_msp430fr5739 _example	P3.6	P3.7	MSP-EXP430FR5739

Note:
It is not required to run the example project on the development kit specified in the table. However, it will help visualize the SUCCESS and FAILURE sequences since the configured pins have an LED connected to the selected pins of the development kits.

IMPORTANT: Before running the examples make sure:

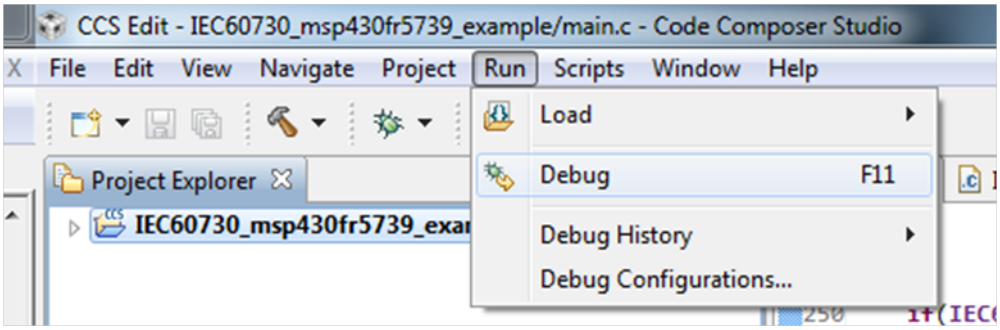
- ACLK is sourced by a 32768 KHz external crystal
- The input pins are set to the expected logic level
  - For IEC60730_msp430f5529_example
    - P3.7 must be set high
- **FOR CCS EXAMPLES ONLY**CRC checksums are loaded to the expected INFO memory address of of the device. To generate the crc checksums file please refer to Generating CRC-CCITT Checksums for examples in CCS
  - IEC60730_msp430g2553_example
    - Address 0x1004
  - IEC60730_msp430f5529_example
    - Expected CRC checksum location for Bank A: 0x1800

  - Expected CRC checksum location for Bank B: 0x1802
  - Expected CRC checksum location for Bank C: 0x1804
  - Expected CRC checksum location for Bank D: 0x1806
- IEC60730_msp430fr5739_example
  - Address 0x1880

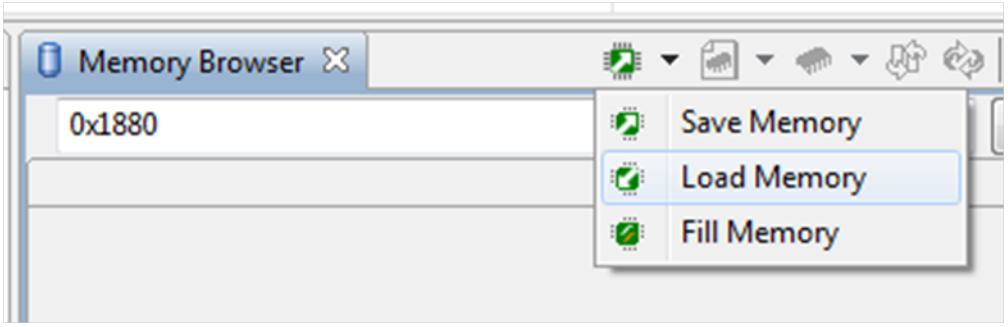
3.2 Generating CRC-CCITT Checksums for examples in CCS

The following steps show how to obtain the CRC-CCITT checksums for the non-volatile memory monitored in the example projects.

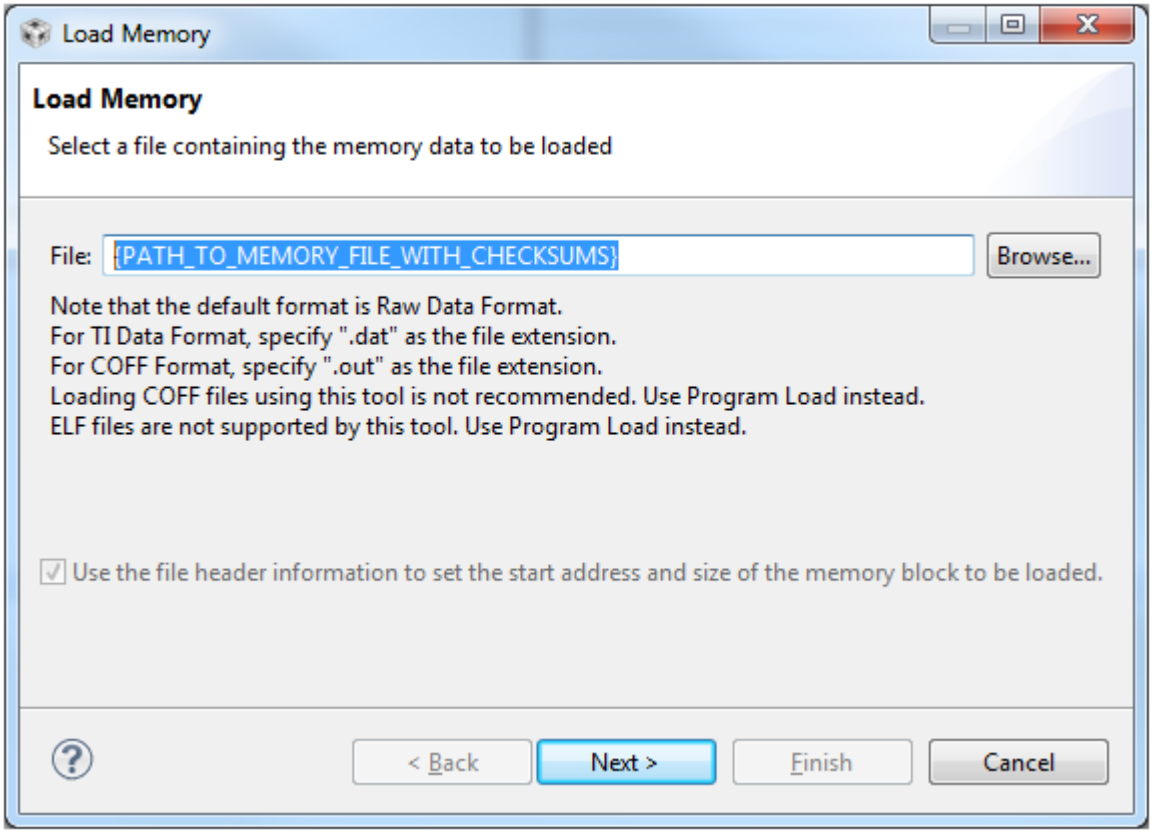
1. After importing the project to CCS and connecting the hardware to your computer. Click on the example project and then go to Run->Debug.



2. Generate the memory file for the example project. To obtain the memory file please refer to Example obtaining memory file in CCS. The number of memory files needed is project dependent:
   - For “IEC60730_msp430fr5739_example".- One memory file is needed. The Start address=0xC200 and number of words= 0x1EC0.
   - For “IEC60730_msp430f5529_example".- Four memory file are needed.
     - File 1.- Start address=0x4400 and number of words= 0x4000.
     - File 2.- Start address=0xC400 and number of words= 0x4000.
     - File 3.- Start address=0x14400 and number of words= 0x4000.
     - File 4.- Start address=0x1C400 and number of words= 0x4000.
   - For “IEC60730_msp430g2553_example".- One memory file is needed. The Start address=0xC000 and number of words= 0x1FE0.
3. Once you have obtained the memory you may use the Configuration Tool included in {IEC60730_ROOT}/utils to generate the memory file with the CRC checksums. For a step-by-step instruction on how to generate the checksums please refer to Generating CRC-CCITT checksum memory file. The tool requires you specify the “CRC checksum location" as an input parameter. Theses are the locations for each example project:
   - For “IEC60730_msp430fr5739_example".- CRC checksum location = 0x1880
   - For “IEC60730_msp430f5529_example".- CRC checksum location = 0x1800
   - For “IEC60730_msp430g2553_example".- CRC checksum location = 0x1004
4. Once you have obtained the file with CRC checksum. Go to “Memory Browser" in CCS and Select “Load Memory".



5. In the “Load Memory" window click “Browse" and select the file which contains the generated checksums. And verify that “Use the file header information to set the start address and size of the memory block to be loaded." is checked. Click “Finish".



3.3 Generating CRC-CCITT Checksums for examples in IAR

IAR examples contain a modified XLINK file that will generate the necessary CRC-CCITT checksums and place them in the expected FLASH/FRAM memory location. For more information on how to modify the XLINK file to automatically generate CRC checksum in IAR please refer to the modified `*.xcl` in every IAR project example and “IAR Linker and Library Tools” documentation which can be found at `{IAR_INSTALL_PATH}\430\doc\xlink.ENU.pdf`. The examples show how to calculate single and multiple CRC-CCITT checksums.

4 Starting a New IEC60730 project

4.1 Introduction

In order to minimize the amount of initial configuration required to start a new IEC60730 project the library includes emptyProject templates for CCS and IAR. The projects can be found in `{IEC60730_PATH}\examples\iec60730\emptyProject`. The following sections provide the steps required to configure your project to be able to use IEC60730 API calls. The following steps show how to properly configure the project:

- Modify the linker command file configuration for PC test.
- Set desired configuration for tests using IEC60730_user_config.h file.

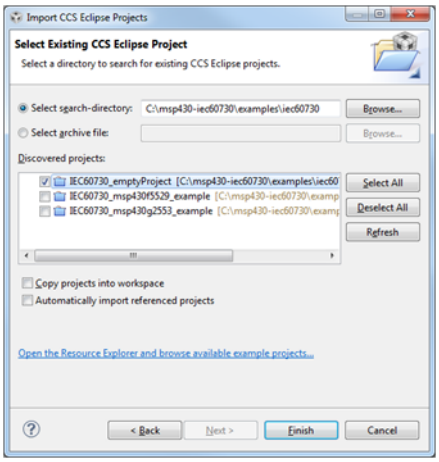
All configurations available for the library are defined in the “IEC60730_user_config.h" file. The default configuration are the following:

- Watchdog enabled (ENABLED_WDT=1)
- Jump to failsafe enabled (JUMP_TO_FAILSAFE=1)
- MCLK frequency of 12MHz (MAIN_CLOCK_FREQUENCY_12MHz is defined)
- MCLK frequency divider 1 (MAIN_CLOCK_DIVIDER=1)
- ACLK is sourced by an external 32768 Hz crystal (LFXT1_FREQUENCY = 32768)
- ACLK frequency divider 1 (LFXT1_FREQUENCY_DIVIDER = 1)
- Allowed frequency drift is +/- 2% (PERCENT_FREQUENCY_DRIFT = 2)
- RAM_START_ADDRESS, RAM_SIZE, STACK_SIZE need to be explicitly defined if not using MSP430F5529 or MSP430G2553.
- March X in non-destructive mode is applied for RAM testing (MARCH_X_TEST and NON_DESTRUCTIVE are not commented).
- The size of the array to store RAM values in non-destructive mode is 8 16bit words (RAM_TEST_BUFSIZE=8).
- The FRAM/FLASH address where the CRC checksum will be stored needs to be defined. If using MSP430F5529 the default location is address 0x1800. If using MSP430G2553 the default location is 0x1004. Finally, if using MSP430FR5739 the default location is 0x1880.
- The allowed ADC count drift is set to +/- 50 (MINIMUM_ADC_COUNT_DRIFT= -50 and MAXIMUM_ADC_COUNT_DRIFT = 50).

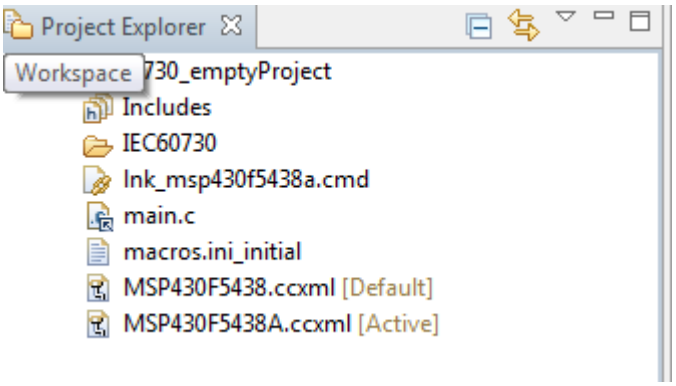
4.2 Starting a New IEC60730 project in CCS

1. Start Code Composer Studio (CCS) and select/create the workspace where you want to import the emptyProject. If this is the first time you run CCS please refer to `CCSv5 Running for the first time`.
2. Import the following projects to your workspace:
   - IEC60730_emptyProject

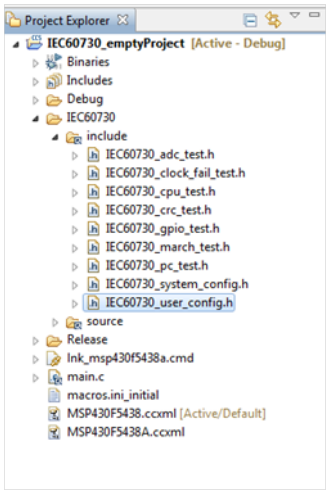
   This project is be located in `IEC60730_PATH\examples\iec60730`. Make sure only the project listed above are selected in the “Import CCS Eclipse Projects" window.



3. If the project was imported correctly you will be able to see the “emptyProject" in your CCS workspace.



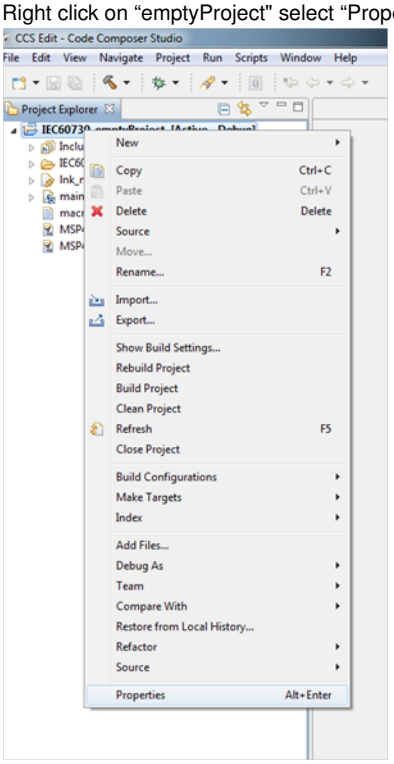
4. The first step is to setup the “IEC60730_user_config.h" file. You can modify this file by double-clicking “IEC60730_user_config.h" file within the “Project Explorer" window.



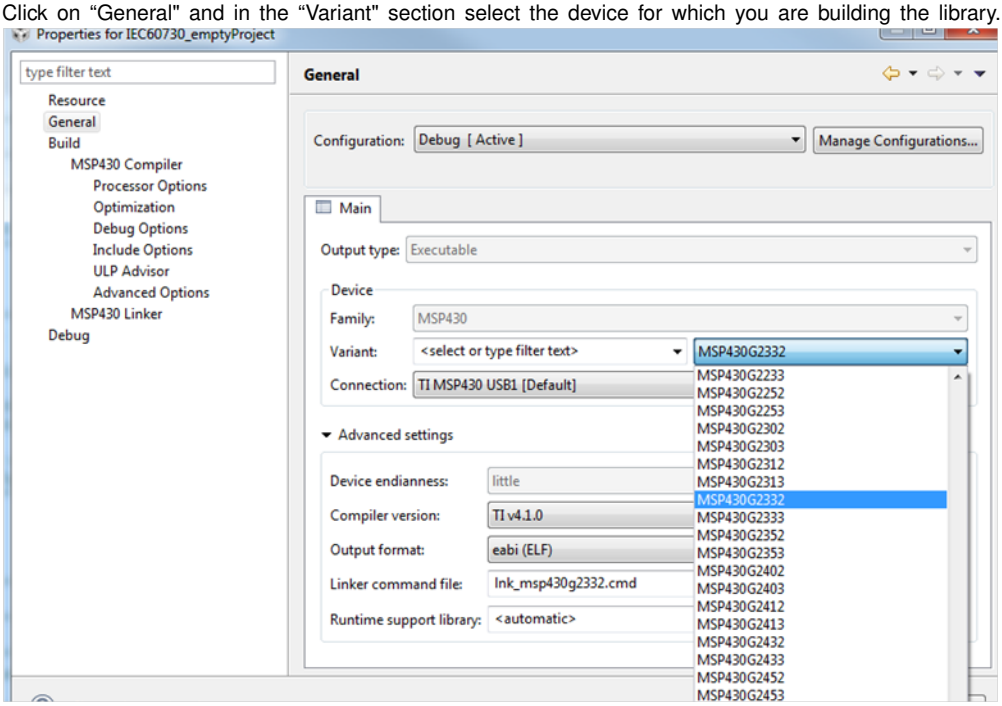
Note:
The sotware package includes a Configuration Tool under `{IEC60730_ROOT}\utils` which allows the users to generate custom “IEC60730_user_config.h". For more information on how to use the Configuration Tool please refer to Generating custom “IEC60730_user_config.h" file .

5. If you are not building the library for a MSP430F5529, MSP430G2553 of MSP430FR5739 you must define RAM_START_ADDRESS, RAM_SIZE, STACK_SIZE in “IEC60730_user_config.h". Or if you are not using the default stack size in your project.
   - To determine RAM_START_ADDRESS value, please consult the “Memory Organization" section of the datasheet for the device that you are building the library for.

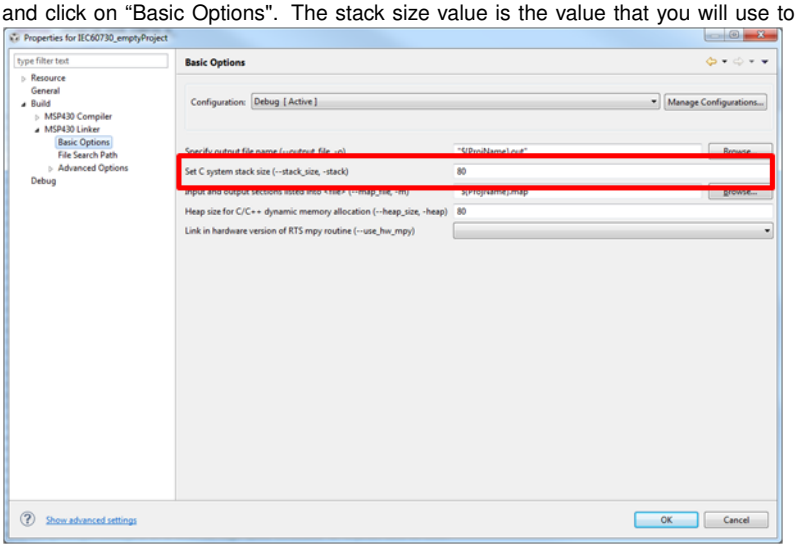
- To determine RAM_SIZE
  - If you are using the RAM test in destructive mode.
    - RAM_SIZE= endAddressOfRamMemory - RAM_START_ADDRESS
  - If you are using the RAM test in non-destructive mode.
    - RAM_SIZE= endAddressOfRamMemory - RAM_START_ADDRESS - 2∗(RAM_TEST_BUFSIZE)
- To determine STACK_SIZE
  - Right click on “emptyProject" select “Properties"



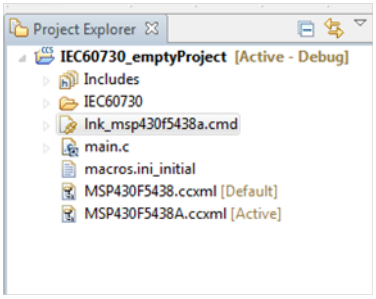
  - Click on “General" and in the “Variant" section select the device for which you are building the library.



- Once you have selected the device, expand the “Build" menu and then expand “MSP430 Linker" menu and click on “Basic Options". The stack size value is the value that you will use to define STACK_SIZE.



6. The Program Counter test requires two test functions to be placed at specific memory locations to check for stuck at bits in Program Counter register. Therefore, the linker command file `lnk_msp430xxxx.cmd` needs to be modified. The linker command file is automatically added to your project when you select the MSP430 variant for the project.



To modify the linker command file follow this steps:

(a) Double-click the `lnk_msp430xxxx.cmd` file. Depending on the device for which the library will be built. The linker command file could have a FLASH section or FLASH and FLASH2 section. The linker command file in `IEC60730_PATH\examples\iec60730\msp430g2553\CCS\` and `IEC60730_PATH\examples\iec60730\msp430f5529\CCS\` shows the modification required to add *PC_TEST_SECTION_1* and *PC_TEST_SECTION_2*. Below is a snapshot of each modification.

- Linker command file with FLASH section only
  - Original linker command file:

```
MEMORY
{
    SFR                     : origin = 0x0000, length = 0x0010
    PERIPHERALS_8BIT        : origin = 0x0010, length = 0x00F0
    PERIPHERALS_16BIT       : origin = 0x0100, length = 0x0100
    RAM                     : origin = 0x0200, length = 0x0100
    INFOA                   : origin = 0x10C0, length = 0x0040
    INFOB                   : origin = 0x1080, length = 0x0040
    INFOC                   : origin = 0x1040, length = 0x0040
    INFOD                   : origin = 0x1000, length = 0x0040
    FLASH                   : origin = 0xF000, length = 0x0FE0
    INT00                   : origin = 0xFFE0, length = 0x0002
    INT01                   : origin = 0xFFE2, length = 0x0002
    INT02                   : origin = 0xFFE4, length = 0x0002
    INT03                   : origin = 0xFFE6, length = 0x0002
    INT04                   : origin = 0xFFE8, length = 0x0002
    INT05                   : origin = 0xFFEA, length = 0x0002
    INT06                   : origin = 0xFFEC, length = 0x0002
    INT07                   : origin = 0xFFEE, length = 0x0002
```

- Modified linker command file:

```
INFOC                   : origin = 0x1040, length = 0x0040
INFOD                   : origin = 0x1000, length = 0x0040
FLASHA                  : origin = 0xC000, length = 0x0554
PC_TEST_SECTION_1       : origin = 0xC554, length = 0x0006
FLASHB                  : origin = 0xC55A, length = 0x3550
PC_TEST_SECTION_2       : origin = 0xFAAA, length = 0x0006
FLASHC                  : origin = 0xFAB0, length = 0x0530
INT00                   : origin = 0xFFE0, length = 0x0002
```

■ Linker command file with FLASH and FLASH2 section

- Original linker command file:

```
MEMORY
{
    SFR                 : origin = 0x0000, length = 0x0010
    PERIPHERALS_8BIT    : origin = 0x0010, length = 0x00F0
    PERIPHERALS_16BIT   : origin = 0x0100, length = 0x0100
    RAM                 : origin = 0x2400, length = 0x4000
    INFOA               : origin = 0x1980, length = 0x0080
    INFOB               : origin = 0x1900, length = 0x0080
    INFOC               : origin = 0x1880, length = 0x0080
    INFOD               : origin = 0x1800, length = 0x0080
    FLASH               : origin = 0x8000, length = 0x7F80
    FLASH2              : origin = 0x10000,length = 0x38000
    INT00               : origin = 0xFF80, length = 0x0002
    INT01               : origin = 0xFF82, length = 0x0002
    INT02               : origin = 0xFF84, length = 0x0002
    INT03               : origin = 0xFF86, length = 0x0002
```

- Modified linker command file:

```
INFOD                   : origin = 0x1800, length = 0x0080
FLASH_A                 : origin = 0x4400, length = 0x1154
PC_TEST_SECTION_1       : origin = 0x5554, length = 0x0006
FLASH_B                 : origin = 0x555A, length = 0x6626
FLASH2_A                : origin = 0x10000,length = 0xAAAA
PC_TEST_SECTION_2       : origin = 0x1AAAA,length = 0x0006
FLASH2_B                : origin = 0x1AAB0,length = 0x9950
INT00                   : origin = 0xFF80, length = 0x0002
INT01                   : origin = 0xFF82, length = 0x0002
```

(b) To determine the origin of each PC_TEST_SECTION please refer to section Location in Memory to Test Program Counter CCS.

(c) Link .pc_test_section_1 and .pc_test_section_2 to the previously defined Memory locations.

```
.pc_test_section_1      : {} > PC_TEST_SECTION_1
.pc_test_section_2      : {} > PC_TEST_SECTION_2
```

(d) Make sure to append all FLASH memory locations to .text , .cinit , .const , .pint , .init_array , *mspabi.exidx* , .mspabi.extab sections accordingly. For an example of how to append FLASH section refer to the linker command files for MSP430G2553 and MSP430F5529 example projects.

(e) If the library will test RAM memory using the non-destructive mode.

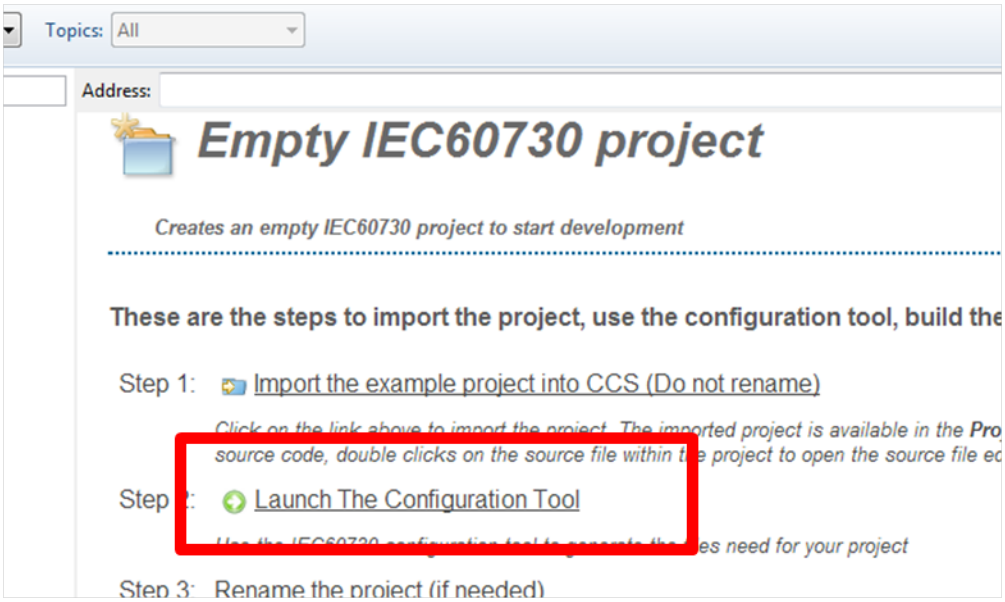
i. MEMORY location in RAM called *IEC60730_SAFE_RAM* needs to be defined in the highest section of RAM with a length of 2∗RAM_TEST_BUFSIZE (defined in “IEC60730_user_config.h").

ii. Define the following section in the linker command file:

```
.safe_ram: {} > IEC60730_SAFE_RAM
```

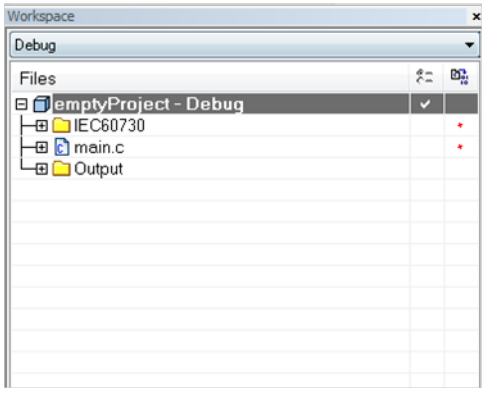
7. Rebuild the emptyProject for the desired MSP430 device.
   - Right click on “IEC60730_emptyProject" select “Properties"
   - Click on “General" and in the “Variant" section select the device for which you are building the library.
   - Click "OK"
   - Right click on “IEC60730_emptyProject" project select “Rebuild Project"
8. The project is ready to run IEC60730 test.

Note:
If importing the IEC example project from MSP430Ware the empty project window will have the option of launching the IEC Configuration Tool. Lauching the tool from this link will set the output path to the location of the project in the IEC60730\include folder of the project.

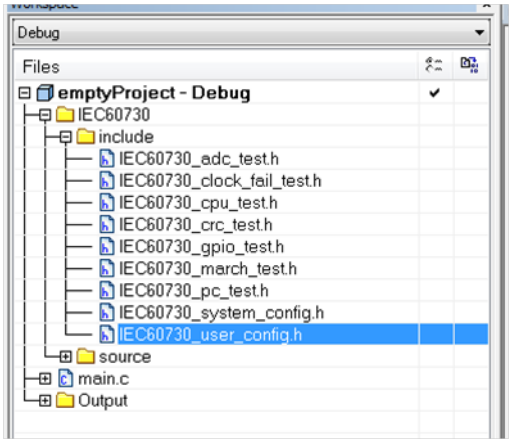


4.3 Starting a New IEC60730 project in IAR

1. Go to `IEC60730_PATH\examples\iec60730\emptyProject\IAR` and double-click on `emptyProject.eww`. When IAR starts click on “Overview" tab in the “Workspace" window you should be able to see the emptyProject int the workspace.

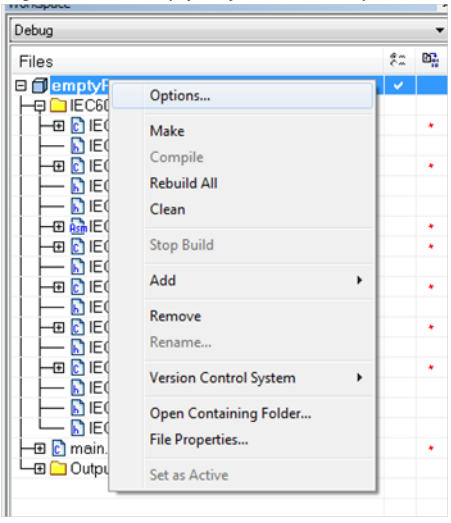


2. The first step if is to setup the “IEC60730_user_config.h" file. You can modify this file by double-clicking “IEC60730_user_config.h" file within the workspace window.

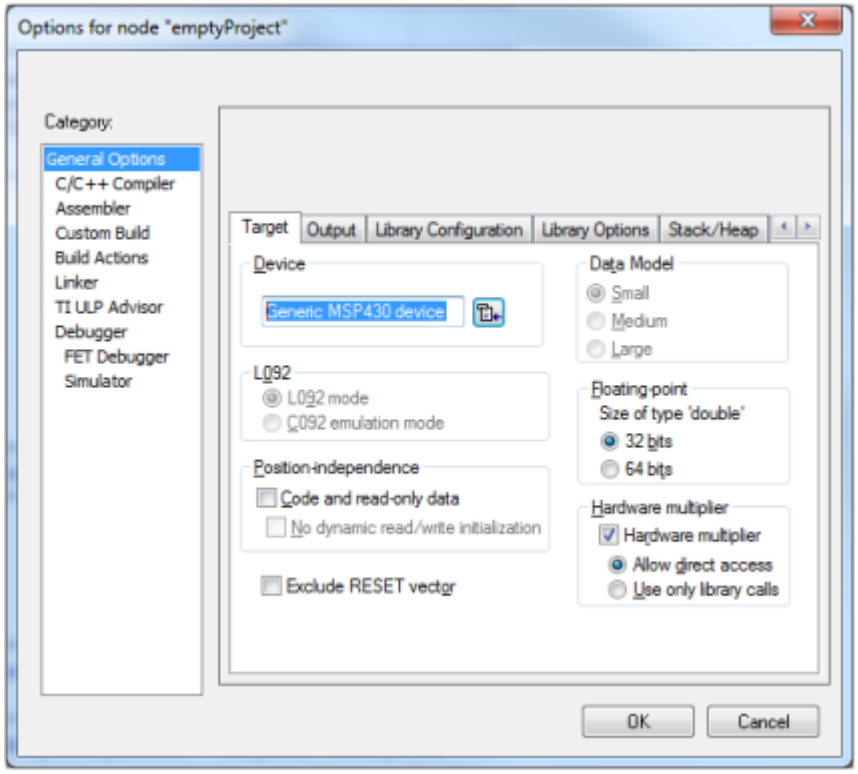


Note:
The sotware package includes a Configuration Tool under `{IEC60730_ROOT}\utils` which allows the users to generate custom “IEC60730_user_config.h". For more information on how to use the Configuration Tool please refer to Generating custom “IEC60730_user_config.h" file .

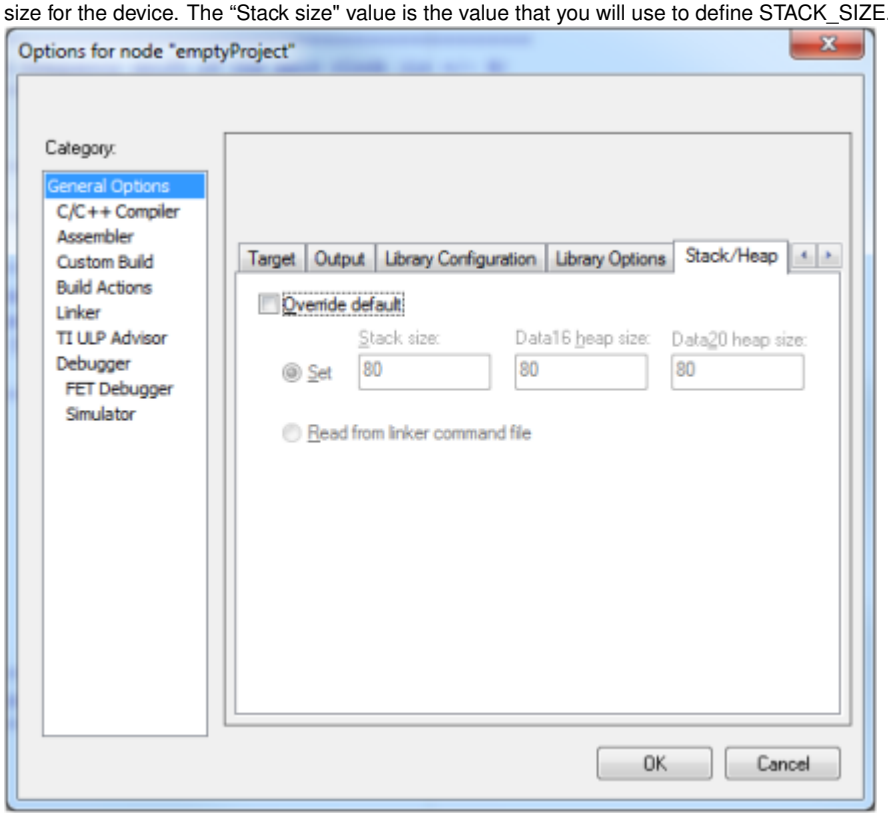
3. If you are not building the library for a MSP430F5529, MSP430G2553 or MSP430FR5739 you must define RAM_START_ADDRESS, RAM_SIZE, STACK_SIZE in “IEC60730_user_config.h". Or if you are not using the default stack size in your project.
   - To determine RAM_START_ADDRESS value, please consult the “Memory Organization" section of the datasheet for the device that you are building the library for.
   - To determine RAM_SIZE
     - If you are using the RAM test in destructive mode.
       - RAM_SIZE= endAddressOfRamMemory - RAM_START_ADDRESS
     - If you are using the RAM test in non-destructive mode.
       - RAM_SIZE= endAddressOfRamMemory - RAM_START_ADDRESS - 2∗(RAM_TEST_BUFSIZE)
   - To determine STACK_SIZE
     - Right click on “emptyProject" select “Options..."



     - In the “Category" window select “General Options" and make sure the “Target" tab is selected. In the device section select the device for which you are building the library.



- Once you have selected the device, select “Stack/Heap" tab. This window will show you the default stack size for the device. The “Stack size" value is the value that you will use to define STACK_SIZE.



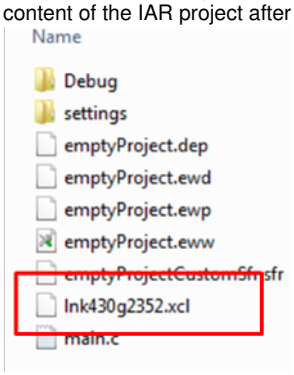
4. The Program Counter test requires two test functions to be placed in a specific location to check for stuck at bits in Program Counter register. Therefore, the linker command file `lnk430xxxx.xcl`, which is located

in `{IAR_INSTALLATION PATH}\IAR Systems\Embedded Workbench x.x\430\config\`, needs to be modified.

WARNING: It is recommended that you create a copy of the linker command in the project location.

To modify the linker command file follow this steps:

(a) Make a copy of the original linker command file and place it in `{IEC60730_PATH}\examples\iec60730\emptyProject\IAR`. The image below shows the folder content of the IAR project after the `.xcl` was copied.



(b) Open `lnk430xxxx.xcl` file in IAR or your preffered text editor and scroll to the *CODE* section.

```
// ----------------------------------------
// Code
//
```

(c) Create PC_TEST_SECTION_1, PC_TEST_SECTION_2 code sections. You can copy and paste the commands shown below:

```
-Z(CODE)PC_TEST_SECTION_1=
-Z(CODE)PC_TEST_SECTION_2=
```

Your *CODE* section should look very similar to the image below:

```
-Z(CODE)PC_TEST_SECTION_1=
-Z(CODE)PC_TEST_SECTION_2=
-Z(CODE)CSTART,ISR_CODE,CODE_ID=F000-FFDF
-P(CODE)CODE=F000-FFDF
```

(d) The final step is to determine the memory location where the functions need to be placed. To determine the memory location and range for each PC_TEST_SECTION please refer to section Location in Memory to Test Program Counter IAR

4.4 Location in Memory to Test Program Counter CCS

MSP430 Device	PC_TEST_SECTION_1 CCS	PC_TEST_SECTION_2 CCS
MSP430G23xx	origin:0xF554,length=0x0008	origin:0xFAAA,length=0x0008
MSP430G24xx	origin:0xEAAA,length=0x0008	origin:0xF554,length=0x0008
MSP430G25xx	origin:0xD554,length=0x0008	origin:0xEAAA,length=0x0008
MSP430F5340, MSP430F5212, MSP430F5217, MSP430F5222, MSP430F5227, MSP430F5324, MSP430F5325, MSP430F5514, MSP430F5515, MSP430F5524, MSP430F5525, MSP430F5341, MSP430F5326, MSP430F5327, MSP430F5517, MSP430F5526, MSP430F5527	origin:0x13D54,length=0x0008	origin:0xC2AA,length=0x0008
MSP430F5342, MSP430F5214, MSP430F5219, MSP430F5224, MSP430F5229, MSP430F5328, MSP430F5329, MSP430F5519, MSP430F5528, MSP430F5529	origin:0x1C2AA,length=0x0008	origin:0x23D54,length=0x0008
MSP430F5513, MSP430F5521, MSP430F5522	origin:0xD554,length=0x0008	origin:0xAAAA,length=0x0008
MSP430F5418A, MSP430F5419A, MSP430F5435A, MSP430F5436A, MSP430F5437A, MSP430F5438A	origin:0x1D554,length=0x0008	origin:0x22AAA,length=0x0008
MSP430F5171, MSP430F5172, MSP430F5310, MSP430F5503, MSP430F5507, MSP430F5510	origin:0xAAAA,length=0x0008	origin:0xD554,length=0x0008
MSP430F5309, MSP430F5502, MSP430F5506, MSP430F5509	origin:0xAAAA,length=0x0008	origin:0xB554,length=0x0008
MSP430F5151, MSP430F5152, MSP430F5308, MSP430F5501, MSP430F5505, MSP430F5508	origin:0xAAAA,length=0x0008	origin:0xC554,length=0x0008
MSP430F5508, MSP430F5131, MSP430F5132, MSP430F5304, MSP430F5500, MSP430F5504	origin:0xE554,length=0x0008	origin:0xFAAA,length=0x0008
MSP430F5333, MSP430F5336, MSP430F5630, MSP430F5633, MSP430F5636, MSP430F5631, MSP430F5634, MSP430F5637, MSP430F5335, MSP430F5338, MSP430F5632, MSP430F5635, MSP430F5638, MSP430F5358, MSP430F5658	origin:0x1D554,length=0x0008	origin:0x22AAA,length=0x0008

4.5 Location in Memory to Test Program Counter IAR

MSP430 Device	PC_TEST_SECTION_1 IAR	PC_TEST_SECTION_2 IAR
MSP430G23xx	F554-F55D	FAAA-FAB3
MSP430G24xx	EAAA-EAB3	F554-F55D
MSP430G25xx	D554-D55d	EAAA-EAB3
MSP430F5340, MSP430F5212, MSP430F5217, MSP430F5222, MSP430F5227, MSP430F5324, MSP430F5325, MSP430F5514, MSP430F5515, MSP430F5524, MSP430F5525, MSP430F5341, MSP430F5326, MSP430F5327, MSP430F5517, MSP430F5526, MSP430F5527	13D54-13D5D	C2AA-C2B3
MSP430F5342, MSP430F5214, MSP430F5219, MSP430F5224, MSP430F5229, MSP430F5328, MSP430F5329, MSP430F5519, MSP430F5528, MSP430F5529	1C2AA-1C2B3	23D54-23D5D
MSP430F5513, MSP430F5521, MSP430F5522	AAAA-AAB3	D554-D55D
MSP430F5418A, MSP430F5419A, MSP430F5435A, MSP430F5436A, MSP430F5437A, MSP430F5438A	1D554-1D55D	22AAA-22AB3
MSP430F5171, MSP430F5172, MSP430F5310, MSP430F5503, MSP430F5507, MSP430F5510	AAAA-AAB3	D554-D55D
MSP430F5309, MSP430F5502, MSP430F5506, MSP430F5509	AAAA-AAB3	B554-B55D
MSP430F5151, MSP430F5152, MSP430F5308, MSP430F5501, MSP430F5505, MSP430F5508	C554-C55D	AAAA-AAB3
MSP430F5508, MSP430F5131, MSP430F5132, MSP430F5304, MSP430F5500, MSP430F5504	E554-E55D	FAAA-FAB3
MSP430F5333, MSP430F5336, MSP430F5630, MSP430F5633, MSP430F5636, MSP430F5631, MSP430F5634, MSP430F5637, MSP430F5335, MSP430F5338, MSP430F5632, MSP430F5635, MSP430F5638, MSP430F5358, MSP430F5658	1D554-1D55D	22AAA-22AB3
MSP430FR5726, MSP430FR5727, MSP430FR5728, MSP430FR5729 MSP430FR5736, MSP430FR5737, MSP430FR5738, MSP430FR5739	D554-D55D	EAAA-EAB3
MSP430FR5722, MSP430FR5723, MSP430FR5724, MSP430FR5725 MSP430FR5732, MSP430FR5733, MSP430FR5734, MSP430FR5735	EAAA-EAB3	F554-F55D
MSP430FR5720, MSP430FR5721, MSP430FR5730, MSP430FR5731	F554-F55D	FAAA-FAB3

5 Analog-to-Digital Converter Test

5.1 Introduction

This functions performs a plausibility check on the ADC10 or ADC12 module. The proper operation of the pin mux selection, and the A/D converter is checked with this function. Before calling this API the user must set three parameters in struct IEC60730_ADC_TEST_adcTest_Handle. This structure has three parameters:

- pinCount this value is the expected ADC conversion result
- useInternalInput specifies if the ADC voltage reference that will be use to make the conversion. The following are acceptable inputs:
  - EXTERNAL_REF
  - INT_REF_1_5_V
  - INT_REF_2_5_V
- muxChannel specifies tha ADC channel that will be tested

If "muxChannel" is set to 2, ADC INCH_2 channel will be sampled. To avoid disabling interrupts in the application the function will poll ADCxxIFG to verify the ADC conversion is complete. The ADC conversion result is compared with "pinCount" value. The user can define the acceptable ADC count drift by adjusting the values of MINIMUM_ADC_COUNT_DRIFT and MAXIMUM_ADC_COUNT_DRIFT macros in "IEC60730_user_config.h" file.

The function may return failure if any of the following errors occur:

- User selected to test ADC module using internal voltage generator, but does not have internal voltage generator enabled.
- User has wrong internal voltage selection (e.g. user is testing with 1.5V internal voltage selection but ADC register are configured for 2.5V internal voltage selection.
- User selected an invalid ADC channel
- FOR ADC12 MODULE ONLY.- If ADC module is not configured in single-conversion mode.
- ADC conversion is out of user defined ADC drift range.

5.2 Type of test

The ADC test checks for fault conditions using plausibility check (H.2.18.13).

5.3 API Functions

Functions

- uint8_t IEC60730_ADC_TEST_testAdcInput (IEC60730_ADC_TEST_adcTest_Handle *adcTestHandle)

5.3.1 Detailed Description

To test the ADC module is operating correctly the following API can be called: IEC60730_ADC_TEST_testAdcInput()

5.3.2 Function Documentation

5.3.2.1 IEC60730_ADC_TEST_testAdcInput

Tests functionality of ADC converter

Prototype:

```
uint8_t
IEC60730_ADC_TEST_testAdcInput(IEC60730_ADC_TEST_adcTest_Handle *adcTestHandle)
```

Parameters:

adcTestHandle contains parameter to test ADC channel.

Description:

This function performs a plausibility check on the ADC10 or ADC12 module. The proper operation of the pin mux selection, and the A/D converter is checked with this function. Before calling this API the user must set values for pinCount, useInternalInput, and muxChannel in IEC60730_ADC_TEST_adcTest_Handle structure. The ADC conversion result is compared with "pinCount" value. The user can define the acceptable ADC count drift by adjusting the values of MINIMUM_ADC_COUNT_DRIFT and MAXIMUM_ADC_COUNT_DRIFT macros in "IEC60730_user_config.h" file.

Modified registers are **ADCxxCTL0**

Returns:

SIG_ADC_TEST.- if the counts provided by the user match the converted counts. TEST_FAILED. - if ADC test fail and JUMP_TO_FAILSAFE is disabled in "IEC60730_user_config.h".

5.4 Programming Example

The following example shows how to use the IEC60730_ADC_TEST_testAdcInput to test internal ADC channels in MSP430G2553 devices

```
// Initialize IEC60730_ADC_TEST_adcTest_Handle
IEC60730_ADC_TEST_adcTest_Handle adcTestHandle;
// Select input channel 1 for ADC
ADC10CTL1 = INCH_8;

// Set-up struct to test ADC input channel 8 with expected value of 0x3FF
// using internal voltage reference of 2.5V
adcTestHandle.muxChannel=8;
adcTestHandle.pinCount=0x3FF;
adcTestHandle.useInternalInput=INT_REF_2_5_V;

IEC60730_ADC_TEST_testAdcInput(&adcTestHandle);
```

The following example shows how to use the IEC60730_ADC_TEST_testAdcInput to test internal ADC channels in MSP430F5529 devices

```
// Initialize IEC60730_ADC_TEST_adcTest_Handle
IEC60730_ADC_TEST_adcTest_Handle adcTestHandle;


//Configure Memory Buffer
/*
Base Addres of ADC12_A Module
Configure memory buffer 0
Map temp sensor to memory buffer 0
Vref+ = Vref+ (int)
Vref- = AVss
Memory buffer 0 is not the end of a sequence
*/
ADC12_A_memoryConfigure(ADC12_A_BASE,
```

```
        ADC12_A_MEMORY_0,
    ADC12_A_INPUT_A8,
    ADC12_A_VREFPOS_INT,
    ADC12_A_VREFNEG_AVSS,
    ADC12_A_NOTENDOFSEQUENCE);

// Set-up struct to test ADC input channel 8 with expected value of 0x3FF
// using internal voltage reference of 2.5V
adcTestHandle.muxChannel=8;
adcTestHandle.pinCount=0x3FF;
adcTestHandle.useInternalInput=INT_REF_2_5_V;

IEC60730_ADC_TEST_testAdcInput(&adcTestHandle);
```

6 CPU Registers Test

6.1 Introduction

This C-callable assembly routine tests CPU core registers for stuck at bits. The following registers are tested:

- R4
- SP
- SR
- R5-R15 The registers are tested in the order listed above

The first register to be tested is R4 since this register is used to store the content of SP and SR. After SP and SR are tested the rest of the registers are tested.

Each register is filled with 0xA value and then read to verify that the register has 0xAAAA or 0xAAAAA. This value depends on whether the library was compiled for a CPU or a CPUX architecture. If the test passes, the same register is filled with 0x5. Afterwards, the register is read to verify the content of the register is 0x5555 or 0x55555, depending on the architecture.

The CPU test will preserve the content of each register.

WARNING: Not all the bits in the SR are tested. This is to prevent the MSP430 going to LPM0 and turning off the CPU. Also R3 is not tested since R3 always reads as 0 and writes to it are ignored.

6.2 Type of test

The CPU test checks for stuck at bits using a static memory test (H.2.19.6). This test should be implemented as a periodic self-test.

6.3 API Functions

Functions

- uint8_t IEC60730_CPU_TEST_testCpuRegisters ()

6.3.1 Detailed Description

To test the CPU register for stuck at bits, the following API can be called: IEC60730_CPU_TEST_testCpuRegisters()

6.3.2 Function Documentation

6.3.2.1 IEC60730_CPU_TEST_testCpuRegisters

Test CPU registers

Prototype:

```
uint8_t
IEC60730_CPU_TEST_testCpuRegisters()
```

Description:

This C-callable assembly routine tests CPU core registers for stuck at bits. The following registers are tested:

- R4
- SP
- SR
- R5-R15 The registers are tested in the order listed above

Modified registers are **R4**, **SP**, **SR**, and **R5-R15**

Returns:

SIG_CPU_REG_TEST.- if test does not detects stuck at bits. TEST_FAILED. - if test detects stuck at bits in CPU registers and JUMP_TO_FAILSAFE is disabled in "IEC60730_user_config.h".

6.4 Programming Example

The following example shows how to use the IEC60730_CPU_TEST_testCpuRegisters.

```
IEC60730_CPU_TEST_testCpuRegisters();
```

7 Clock Fail Test

7.1 Introduction

The following function verifies that MCLK is oscillating at the frequency specified by the MAIN_CLOCK_FREQUENCY macro. The user must define the allowed +/- percentage frequency drift using the macro PERCENT_FREQUENCY_DRIFT in "IEC60730_user_config.h". The test passes if freqCounter is between FREQUENCY_COUNT_MAX and FREQUENCY_COUNT_MIN. TA0 must be sourced by ACLK with a high precision clock source. To increase accuracy of oscillator measurement, it is suggested to source LF or XT1 with a 32768 Hz crystal. If the application uses a different frequency for LF or XT1, the LFXT1_FREQUENCY macro in "IEC60730_user_config.h" file must be updated with correct frequency.

NOTE: The test requires TA0 to be source by ACLK, and configured in Up mode. Also, TAIE will be disabled. Therefore, if the application requires TAIE to be enabled the user must set TAIE upon test completion.

7.2 Type of test

The Clock Fail Test API checks for wrong frequency using frequency monitoring (H.2.18.10.1)

7.3 API Functions

Functions

- uint8_t IEC60730_OSCILLATOR_TEST_testOsc ()

7.3.1 Detailed Description

To test that MCLK is oscillating at the user defined frequency the following API can be called: IEC60730_OSCILLATOR_TEST_testOsc()

7.3.2 Function Documentation

7.3.2.1 IEC60730_OSCILLATOR_TEST_testOsc

Tests MCLK for proper operation at user defined frequency.

Prototype:

```
uint8_t
IEC60730_OSCILLATOR_TEST_testOsc()
```

Description:

The following function verifies that MCLK is oscillating at the frequency specified by the MAIN_CLOCK_FREQUENCY macro. The user must define the allowed +/- percentage frequency drift using the macro PERCENT_FREQUENCY_DRIFT in "IEC60730_user_config.h". The test is passed if freqCounter is between FREQUENCY_COUNT_MAX and FREQUENCY_COUNT_MIN. TAx must be source by ACLK with a high precision clock source. To increase accuracy of oscillator measurement, it is suggested to source LF or XT1 with a 32768 Hz crystal. If the application uses a different frequency for LF or XT1, the LFXT1_FREQUENCY macro in "IEC60730_user_config.h" file must be updated with correct frequency.

NOTE: The test requires TAx to be source by ACLK, and configured in Up mode. Also, TAIE will be disable. Therefore, if the application requires TAIE to be enable, the user must set TAIE upon test completion.

Modified registers are **TAxCCRO**, **TAxCCTL0**, and **TAxCTL**

Returns:

SIG_CLOCK_TEST .- If test is passed. TEST_FAILED. - if ADC test fail and JUMP_TO_FAILSAFE is disabled in "IEC60730_user_config.h".

7.4 Programming Example

The following example shows how to use the IEC60730_OSCILLATOR_TEST_testOsc.

```
IEC60730_OSCILLATOR_TEST_testOsc();
```

7.5 Using different Timer

By default TA0 is used to monitor the frequency of MCLK. If required by the application, a different timer can be used to generate the 10 msec interval. To use a different timer `IEC60730_clock_fail_test.c` needs to be modified. In the file replace all TA0 registers for the desired TAx to be used by the test. Finally, go to `IEC60730_user_config.h` file and update TA0CCR0_VALUE_FOR_10_mSEC for TAxCCR0_VALUE_FOR_10_mSEC, where x is the timer that you want to use.

8 Non Volatile Memory Test

8.1 Introduction

The following function checks for memory corruption in non volatile memory. The user must first calculate the CRC-CCITT value of the memory to be checked. This can be achieved by using the CRC_tool which is included in the utils folders of the library.

If the library is built for an MSP430 device that has a CRC module, the API will take advatange of the CRC module and calculate the CRC in hardware. Otherwise the CRC is calculated in software.

Before calling the function the user must calculate the CRC of non volatile memory and store it in FLASH/FRAM memory.

The memorySize parameter is specified in 16 bit words and should not exceed 65535 16 bit words.

The expectedCrc value is compared to the newly calculated CRC value. The test passes if the two CRC values are identical.

To determine the start address and size of non volatile memory for each MSP430 device, please consult the device datasheet.

8.2 Type of test

The CRC test checks for single bit faults using word protection with multi-bit redundancy (H.2.19.8.1)

8.3 API Functions

Functions

- uint8_t IEC60730_CRC_TEST_testNvMemory (uint16_t *pStartAddress, uint16_t memorySize, uint16_t *pExpectedCrc)

8.3.1 Detailed Description

To test for memory corruption in non volatile memory the following API can be called: IEC60730_CRC_TEST_testNvMemory()

8.3.2 Function Documentation

8.3.2.1 IEC60730_CRC_TEST_testNvMemory

Tests invariable (non volatile) memory (FLASH)

Prototype:

```
uint8_t
IEC60730_CRC_TEST_testNvMemory(uint16_t *pStartAddress,
                               uint16_t memorySize,
                               uint16_t *pExpectedCrc)
```

Parameters:

pStartAddress is a pointer the start address of memory to be tested

memorySize size of memory to be tested

pExpectedCrc is a pointer to the expected CRC value

Description:

The following function check for memory corruption in non volatile memory. The user must first calculate the CRC value of the memory to be checked. This can be achieved by using the CRC_tool which is included in the utils folders of the library. To learn how to use the CRC_tool please consult the IEC60730 Class B API User's Guide. When the CRC value is obtain, the user must store the CRC value in FLASH before calling the function. The memorySize paramater is specified in 16 bit words and should not exceed 65535 16 bit words. The expectedCrc value is compared to the newly calculated CRC value. The test passes if the two CRC values are identical.

NOTE: memorySize should be even an value, otherwise the the test fails.

Returns:

SIG_NV_MEM_CRC_TEST.- if expected CRC and calculated CRC are identical. TEST_FAILED. - if non volatile test fail and JUMP_TO_FAILSAFE is disabled in "IEC60730_user_config.h".

8.4 Programming Example

The following example shows how to use the IEC60730_CRC_TEST_testNvMemory.

```
IEC60730_CRC_TEST_testNvMemory((uint16_t*)0xc000,0x3fd0,(uint16_t*)CRC_CHECKSUM_LOCATION);
```

9 General Purpose I/O Test

9.1 Introduction

The following functions will perform output and input plausibility checks on the GPIO module. When testing an output the function sets and clears the pin specified by gpioPin. The test passes if the function is able to set and clear the BITX on PXOUT. When testing an input the function compares the current state in PxIN with the expectedValue and the test passes if both values are equal.

The function will check if the user has passed valid port and gpioPin values. If the MSP430 device does not have the selected PORTx or if the value value for gpioPin is outside the valid range, the function will call IEC60730_FAIL_SAFE_failSafe() if JUMP_TO_FAILSAFE is enabled in "IEC60730_user_config.h", otherwise TEST_FAILURE is returned.

The valid parameters for gpioPin:

- PORT1-PORT11 valid range (0x0000-0x00FF)
- PORTA-PORTF valid range (0x0000-0xFFFF)
- PORTJ valid range (0x0000-0x000F)

NOTE: PORT will retain after function call.

9.2 Type of test

The GPIO test checks for faul conditions using plausibility check (H.2.18.13).

9.3 API Functions

Functions

- uint8_t IEC60730_GPIO_TEST_testGpioInput (uint16_t port, uint16_t gpioPin, uint16_t expectedValue)
- uint8_t IEC60730_GPIO_TEST_testGpioOutput (uint16_t port, uint16_t gpioPin)

9.3.1 Detailed Description

To test the GPIO module is operating correctly the following APIs can be called: IEC60730_GPIO_TEST_testGpioOutput() IEC60730_GPIO_TEST_testGpioInput()

9.3.2 Function Documentation

9.3.2.1 IEC60730_GPIO_TEST_testGpioInput

Tests input functionality of GPIO module

Prototype:

```
uint8_t
IEC60730_GPIO_TEST_testGpioInput(uint16_t port,
                                 uint16_t gpioPin,
                                 uint16_t expectedValue)
```

Parameters:

port is the port number to be tested. Consult device datasheet to determine which ports are available in your device. Valid values are **PORT_1 PORT_2 PORT_3 PORT_4 PORT_5 PORT_6 PORT_7 PORT_8 PORT_9 PORT_10 PORT_11 PORT_A PORT_B PORT_C PORT_D PORT_E PORT_F PORT_J**

gpioPin is the GPIO pin number(s) that will be test. The following values can be ORed to test multiple pins. Valid values are **PIN0 PIN1 PIN2 PIN3 PIN4 PIN5 PIN6 PIN7 PIN8 PIN9 PIN10 PIN11 PIN12 PIN13 PIN14 PIN15**

expected is the GPIO pin number(s) that will be test. Valid values are **PIN0_HIGH PIN0_LOW PIN1_HIGH PIN1_LOW PIN2_HIGH PIN2_LOW PIN3_HIGH PIN3_LOW PIN4_HIGH PIN4_LOW PIN5_HIGH PIN5_LOW PIN6_HIGH PIN6_LOW PIN7_HIGH PIN7_LOW PIN8_HIGH PIN8_LOW PIN9_HIGH PIN9_LOW PIN10_HIGH PIN10_LOW PIN11_HIGH PIN11_LOW PIN12_HIGH PIN12_LOW PIN13_HIGH PIN13_LOW PIN14_HIGH PIN14_LOW PIN15_HIGH PIN15_LOW**

Description:

This function performs an input plausibility check on the GPIO module. The function compares the current state in PxIN with the expectedValue and the test is passed if both values are equal. If the MSP430 device does not have the selected PORTx or if the value value for gpioPin is outside the valid range, the function will call IEC60730_FAIL_SAFE_failSafe() if JUMP_TO_FAILSAFE is enabled in "IEC60730_user_config.h" otherwise TEST_FAILURE is returned.

These are the valid parameters for gpioPin: -PORT1-PORT11 valid range (0x0000-0x00FF) -PORTA-PORTF valid range (0x0000-0xFFFF) -PORTJ valid range (0x0000-0x000F)

Returns:

If the test passes.- SIG_GPIO_TEST If the test fails.- TEST_FAILURE

9.3.2.2 IEC60730_GPIO_TEST_testGpioOutput

Tests output functionality of GPIO module

Prototype:

```
uint8_t
IEC60730_GPIO_TEST_testGpioOutput(uint16_t port,
                                  uint16_t gpioPin)
```

Parameters:

port is the port number to be tested. Consult device datasheet to determine which ports are available in your device. Valid values are **PORT_1 PORT_2 PORT_3 PORT_4 PORT_5**

PORT_6 PORT_7 PORT_8 PORT_9 PORT_10 PORT_11 PORT_A PORT_B PORT_C PORT_D PORT_E PORT_F PORT_J

gpioPin is the GPIO pin number(s) that will be test. The following values can be ORed to test multiple pins. Valid values are **PIN0 PIN1 PIN2 PIN3 PIN4 PIN5 PIN6 PIN7 PIN8 PIN9 PIN10 PIN11 PIN12 PIN13 PIN14 PIN15**

Description:

This function performs an output plausibility check on the GPIO module. The function sets and clears the pin specified by gpioPin. The function will check if the user has passed valid port and gpioPin values. If the MSP430 device does not have the selected PORTx or if the value value for gpioPin is outside the valid range, the function will call IEC60730_FAIL_SAFE_failSafe() if JUMP_TO_FAILSAFE is enabled in "IEC60730_user_config.h", otherwise TEST_FAILURE is returned.

These are the valid parameters for gpioPin: -PORT1-PORT11 valid range (0x0000-0x00FF) -PORTA-PORTF valid range (0x0000-0xFFFF) -PORTJ valid range (0x0000-0x000F)

PxOUT are modified by this test but the original state of PxOUT, if test is PASSED.

Modified registers are **PxOUT**.

Returns:

If the test passes.- SIG_GPIO_TEST If the test fails.- TEST_FAILURE

9.4 Programming Example

The following example shows how to use the IEC60730_GPIO_TEST_testGpioOutput and IEC60730_GPIO_TEST_testGpioInput.

```
// Code to test outputs
IEC60730_GPIO_TEST_testGpioOutput(PORT_2, PIN0|PIN1|PIN2);
//Code to test inputs
IEC60730_GPIO_TEST_testGpioInput(PORT_1, PIN3|PIN4|PIN5, PIN3_LOW|PIN4_HIGH|PIN5_HIGH);
```

10 Variable Memory Test

10.1 Introduction

This function checks RAM memory for DC fault using march test. MarchC and MarchX can be run in destructive or non-destructive mode based on the macro definition of MARCH_X_TEST or MARCH_C_TEST in "IEC60730_user_config.h" file. The macros for RAM_START_ADDRESS and RAM_END_ADDRESS are defined in "IEC60730_user_config.h" file. to determine the correct start and end address for ram please consult the MSP430 datasheet.

The test will perform the desired march test over the range of RAM memory specified by pui16_StartAddr and pui16_EndAddr.

When the test is run in NON-DESTRUCTIVE mode, the SAFE_RAM_BUFFER is used to store the current content of ram to be tested. The first task performed by the test is to check for DC faults on the SAFE_RAM_BUFFER. Once the buffer is checked, the test cotinues checking the rest of RAM memory.

NOTE: If the march test is going to be run in NON-DESTRUCTIVE mode in CCS the linker command file (∗.cmd) needs to have a section called ".safe_ram". For more information on how to define this section in the linker command file please refer to the sample project and inspect the linker command files associated with the projects.

10.2 Type of test

The MARCH test checks for DC fault using static memory tests (H.2.19.6). This test should be implemented as a periodic self-test.

10.3 API Functions

Functions

- uint8_t IEC60730_MARCH_TEST_testRam (uint16_t ∗pui16_StartAddr, uint16_t ∗pui16_EndAddr)

10.3.1 Detailed Description

To test the volatile memory for DC fault, the following APIscan be called: IEC60730_MARCH_TEST_testRam()

10.3.2 Function Documentation

10.3.2.1 IEC60730_MARCH_TEST_testRam

Tests Variable memory (RAM memory)

Prototype:

```
uint8_t
IEC60730_MARCH_TEST_testRam(uint16_t *pui16_StartAddr,
                            uint16_t *pui16_EndAddr)
```

Parameters:

∗***pui16_StartAddr*** is the start address of RAM to be tested

∗***pui16_EndAddr*** is the end address of RAM to be tested

Description:

This function checks the RAM memory for DC fault using march test. The following march tests are implemented. Both test can be run in destructive or non-destructive mode based on the macro definition of MARCH_X_TEST or MARCH_C_TEST in "IEC60730_user_config.h" file

- March X
- March C

The test will perform the desired march test over the range of RAM memory specified by pui16_StartAddr and pui16_EndAddr.

Returns:

SIG_RAM_TEST.- if RAM test is passed TEST_FAILED. - if RAM test fail and JUMP_TO_FAILSAFE is disabled in "IEC60730_user_config.h".

10.4 Programming Example

The following example shows how to use IEC60730_MARCH_TEST_testRam.

```
IEC60730_MARCH_TEST_testRam((uint16_t*)RAM_START_ADDRESS,
                                                    (uint16_t*)RAM_END_ADDRESS);
```

11 Program Counter Register Test

11.1 Introduction

This function tests the Program Counter register for stuck at bits. The routine calls two test functions that return their addresses. Their return values are compared to the PC test function address. If the value matches, the function passes, if not it fails. The PC test functions need to reside in separate memory locations such that, by the time all of the functions are called, all the Program Counter register bits are set or cleared, thus indirectly testing the PC register for stuck at bits. The user must define two sections named "pc_test_section_1", "pc_test_section_2" in the linker command file. The example project contains a modified linker command file with both sections defined.

In the example code provided for MSP430G2553 devices the PC test functions have the following memory address locations in the specified sections.

- pcTestFunction1 - (0xD554) pc_test_section_1
- pcTestFunction2 - (0xEAAA) pc_test_section_2 In the example code provided for MSP430F5529 devices the PC test functions have the following memory address locations in the specified sections.
- pcTestFunction1 - (0x23D54) pc_test_section_1
- pcTestFunction2 - (0x1C2AA) pc_test_section_2

11.2 Type of test

The PC test checks for stuck at bits using logical monitoring of the program counter (H.2.18.10.2). This test should be implemented as a periodic self-test.

11.3 API Functions

Functions

- uint8_t IEC60730_PC_TEST_testPcRegister (void)

11.3.1 Detailed Description

To test the PC register for stuck at bits the following API can be called: IEC60730_PC_TEST_testPcRegister()

11.3.2 Function Documentation

11.3.2.1 IEC60730_PC_TEST_testPcRegister

Tests Program Counter register for stuck at bits

Prototype:

```
uint8_t
IEC60730_PC_TEST_testPcRegister(void)
```

Description:

This function tests the Program Counter register for stuck at bits. The routine call two test functions that return their addresses. Their return values are compared to the PC test function address. If the value matches, the function passes, if not it fails. The PC test functions need to reside in separate memory locations such that , by the time all of them are called, all the Program Counter register bits are set or cleared. Thus indirectly testing the PC register for stuck at bits. The user must define two sections named "pc_test_section_1", "pc_test_section_2"

Modified registers are **REGISTER_1**, **REGSITER_2**, and **REGISTER_3**

Returns:

None

11.4 Programming Example

The following example shows how to use the IEC60730_PC_TEST_testPcRegister

```
IEC60730_PC_TEST_testPcRegister();
```

12 IEC60730 Class B API execution times and Code Size

12.1 Introduction

The following section shows the API execution times for the example projects included in this software package. The example projects were developed for MSP430G2553 , MSP430F5529 and MSP430FR5739 devices.

12.2 IEC60730 Class B API Execution Time and Code Size MSP430G2553 CCS

The MSP430G2553 device was tested on the MSP430 LaunchPad Value Line Development kit (MSP-EXP430G2). MCLK was sourced by the integrated digitally controlled oscillator (DCO) with a frequency of 12 MHz. ACLK was source by an external 32768 Hz crystal. Finally, the Analog-to-Digital Converter (ADC) was configured to use the internal voltage generator to test the execution of the API. The projects were built on Texas Instruments Code Composer Studio5.3 using TI compiler v4.1.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	19.91 usec	736
IEC60730_ PC_TEST_testPcRegister	7.66 usec	160
IEC60730_ OSCILLA-TOR_TEST_testOsc	9.97 msec	152
IEC60730_ INTER-RUPT_TEST_testInterrupt	35.54 usec	336
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	9.49 msec	676
using March X algorithm (destructive mode)	8.64 msec	
using March C algorithm (non-destructive mode)	18.16 msec	
using March C algorithm (destructive mode)	16.96 msec	
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	168.37 msec	272
IEC60730_ ADC_TEST_testAdcInput	16.20 usec	308
IEC60730_ GPIO_TEST_testGpioOutput	34.62 usec	412
IEC60730_ GPIO_TEST_testGpioInput	46.70 usec	460

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

12.3 IEC60730 Class B API Execution Time and Code Size MSP430G2553 IAR

The MSP430G2553 device was tested on the MSP430 LaunchPad Value Line Development kit (MSP-EXP430G2). MCLK was sourced by the integrated Digitally Controlled Oscillator (DCO) with a frequency of 12 MHz. ACLK was source by an external 32768 Hz crystal. Finally, the Analog-to-Digital Converter (ADC) was configured to use the internal voltage generator to test the execution of the API. The projects were built on IAR Embedded Workbench®5.51.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	18.50 usec	358
IEC60730_ PC_TEST_testPcRegister	8.33 usec	88
IEC60730_ OSCILLA-TOR_TEST_testOsc	9.99 msec	78
IEC60730_ INTER-RUPT_TEST_testInterrupt	35.54 usec	166
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	10.89 msec	326
using March X algorithm (destructive mode)	8.64 msec	186
using March C algorithm (non-destructive mode)	20.79 msec	416
using March C algorithm (destructive mode)	19.35 msec	276
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	178.52 msec	134
IEC60730_ ADC_TEST_testAdcInput	13.95 usec	176
IEC60730_ GPIO_TEST_testGpioOutput	50.83 usec	414
IEC60730_ GPIO_TEST_testGpioInput	38.95 usec	378

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

12.4 IEC60730 Class B API Execution Time and Code Size MSP430F5529 CCS

The MSP430F5529 device was tested on the MSP430F5529 USB ExperimenterŠs Board (MSP-EXP430F5529). MCLK was sourced by the DCO with a frequency of 12 MHz. ACLK was sourced by an external 32768 Hz crystal. The project was built on Code Composer Studio 5.3 using TI compiler v4.1.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	26.50 usec	732
IEC60730_ PC_TEST_testPcRegister	15.58 usec	220
IEC60730_ OSCILLA-TOR_TEST_testOsc	10.01 msec	152
IEC60730_ INTER-RUPT_TEST_testInterrupt	54.29 usec	672
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	171.92 msec	660
using March X algorithm (destructive mode)	162.00 msec	348
using March C algorithm (non-destructive mode)	329.31 msec	844
using March C algorithm (destructive mode)	318.73 msec	532
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	19.13 msec	164
IEC60730_ ADC_TEST_testAdcInput	19.29 usec	312
IEC60730_ GPIO_TEST_testGpioOutput	41.29 usec	612
IEC60730_ GPIO_TEST_testGpioInput	52.20 usec	664

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

12.5 IEC60730 Class B API Execution Time and Code Size MSP430F5529 IAR

The MSP430F5529 device was tested on the MSP430F5529 USB ExperimenterŠs Board (MSP-EXP430F5529). MCLK was sourced by the DCO with a frequency of 12 MHz. ACLK was sourced by an external 32768 Hz crystal. The project was built on IAR Embedded Workbench®5.51.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	27.04 usec	368
IEC60730_ PC_TEST_testPcRegister	19.08 usec	106
IEC60730_ OSCILLA-TOR_TEST_testOsc	10.01 msec	78
IEC60730_ INTER-RUPT_TEST_testInterrupt	55.12 usec	672
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	186.61 msec	318
using March X algorithm (destructive mode)	174.40 msec	184
using March C algorithm (non-destructive mode)	356.57 msec	406
using March C algorithm (destructive mode)	343.43 msec	272
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	24.59 msec	94
IEC60730_ ADC_TEST_testAdcInput	21.33 usec	164
IEC60730_ GPIO_TEST_testGpioOutput	44.87 usec	501
IEC60730_ GPIO_TEST_testGpioInput	34.33 usec	474

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

12.6 IEC60730 Class B API Execution Time and Code Size MSP430FR5739 CCS

The MSP430FR5739 device was tested on the MSP-EXP430FR5739. MCLK was sourced by the DCO with a frequency of 12 MHz. ACLK was sourced by an external 32768 Hz crystal. The project was built on Code Composer Studio v 5.3 using TI compiler v4.1.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	31.70 usec	732
IEC60730_ PC_TEST_testPcRegister	18.29 usec	220
IEC60730_ OSCILLA-TOR_TEST_testOsc	10.009 msec	152
IEC60730_ INTER-RUPT_TEST_testInterrupt	271 usec	964
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	19.02 msec	660
using March X algorithm (destructive mode)	17.58 msec	348
using March C algorithm (non-destructive mode)	36.47 msec	844
using March C algorithm (destructive mode)	34.62 msec	532
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	11.25 msec	164
IEC60730_ ADC_TEST_testAdcInput	21.50 usec	364
IEC60730_ GPIO_TEST_testGpioOutput	64.04 usec	472
IEC60730_ GPIO_TEST_testGpioInput	50.00 usec	524

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

12.7 IEC60730 Class B API Execution Time and Code Size MSP430FR5739 IAR

The MSP430FR5739 device was tested on the MSP-EXP430FR5739. MCLK was sourced by the DCO with a frequency of 12 MHz. ACLK was sourced by an external 32768 Hz crystal. The project was built on IAR Embedded Workbench®5.51.3 with no optimization.

API Name	Execution Time	Code Size (Bytes)
IEC60730_ CPU_TEST_testCpuRegisters	24.08 usec	368
IEC60730_ PC_TEST_testPcRegister	15.54 usec	112
IEC60730_ OSCILLA-TOR_TEST_testOsc	10.007 msec	78
IEC60730_ INTER-RUPT_TEST_testInterrupt	260 msec	406
IEC60730_ MARCH_TEST_testRam size (416 Bytes)		
using March X algorithm (non-destructive mode)	23.60 msec	316
using March X algorithm (destructive mode)	21.74 msec	184
using March C algorithm (non-destructive mode)	45.23 msec	404
using March C algorithm (destructive mode)	42.82 msec	272
IEC60730_ CRC_TEST_testNvMemory (16KB) in software	13.54 msec	94
IEC60730_ ADC_TEST_testAdcInput	17.41 usec	200
IEC60730_ GPIO_TEST_testGpioOutput	47.00 usec	434
IEC60730_ GPIO_TEST_testGpioInput	33.66 usec	404

The example project will run all the APIs mentioned above and in case any of the tests fails, the program will call IEC60730_FAIL_SAFE_failSafe function.

13 Using the MSP430 IEC60730 Software Package Configuration Tool

13.1 Introduction

The MSP430 IEC60730 Software Package Configuration Tool allows the user to generate custom IEC60730_user_config.h header files using a Graphical User Interface. The configuration tool allows the user to obtain two essential files needed to run the self test:

- "IEC60730_user_config_custom.h" header file.- Used at compilation time to configure MSP430 IEC60730 Software Package self tests.
- Memory file in 16-bit C-style (∗.dat) file or MSP-430 TXT file (∗.txt) containing crc checksum(s) used in non-voltaile memory test.

Requirements to generate "IEC60730_user_config_custom.h" header file:

- RAM_START_ADDRESS
- RAM_SIZE
- STACK_SIZE

The value of these fields are device dependent. To determine the correct values for please refer to step #5 on Starting a New IEC60730 project in CCS. The same instructions apply if you are developing on IAR.

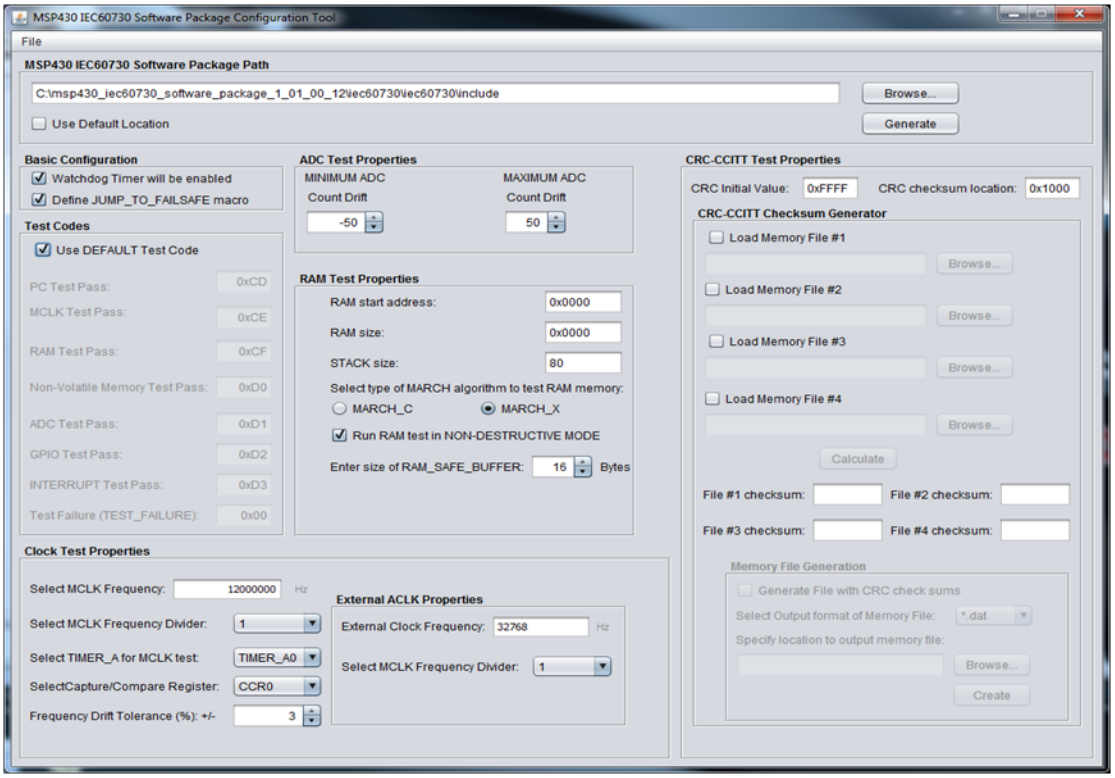
Requirements to generate CRC-CCITT checksum memory file:

- Single segment memory content file in 16-bit C-style (∗.dat) file or MSP-430 TXT file (∗.txt) to be monitored using non-voltile test.

13.2 Running Configuration Tool

The software requirements to run the tool are: -Java 1.5 or later -The tool can be run in Windows and Linux OS.

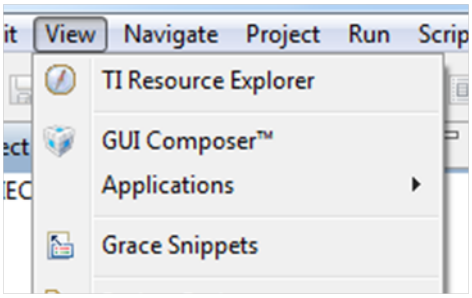
To run the tool just double-click in the executable jar file "MSP430_IEC60730_Config_Tool.jar" which is located in: `{IEC60730_ROOT}\utils` directory. Below is a snapshot of the MSP430 IEC60730 Software Package Configuration Tool.



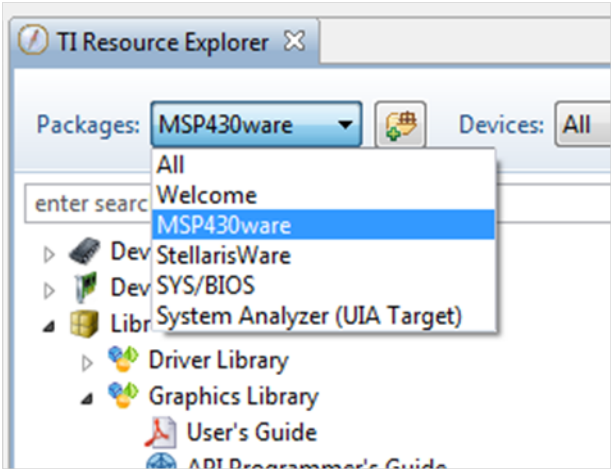
13.3 Launching Configuration Tool from TI Resource Explorer

If you download MSP430 IEC60730 Software Package as part of MSP430Ware, you will have the option to launch the IEC configuration tool from TI Resource Explorer.

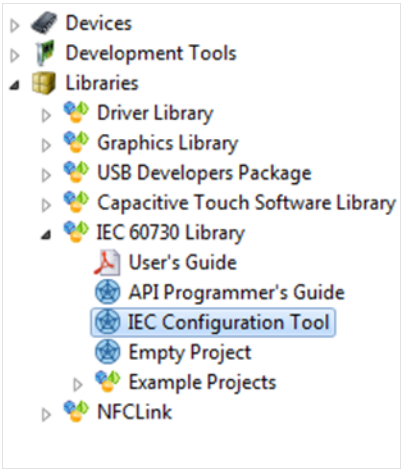
To launch the IEC configuration tool, go to TI Resource Explorer windows View -> TI Resource Explorer.



Under Packages select MSP430ware.



Expand Libraries and IEC 60730 Library and IEC Configuration Tool.



Finally, click on the "Launch IEC60730 Configuration Tool".

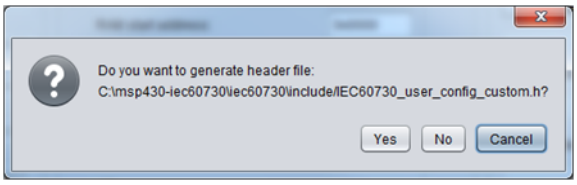
13.4 Generating custom “IEC60730_user_config.h" file

The default output location of the header file is `{IEC60730_ROOT}\iec60730\include` . If the tool is run from a different directory the output directory path needs to be updated. The following steps show how to update the output path:

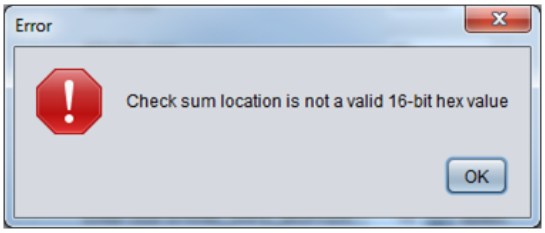
1. Uncheck the “Use Default Location".

2. After removing the check mark, click the “Browse..." button and point to the following directory `{IEC60730_ROOT}\iec60730\include`

Once you have filled with the desired values, click the “Generate" button. If you have entered the valid values, you will be prompted by a dialog box as the one shown below.



In case a field has invalid data content an error message similar to the one below will be generated.

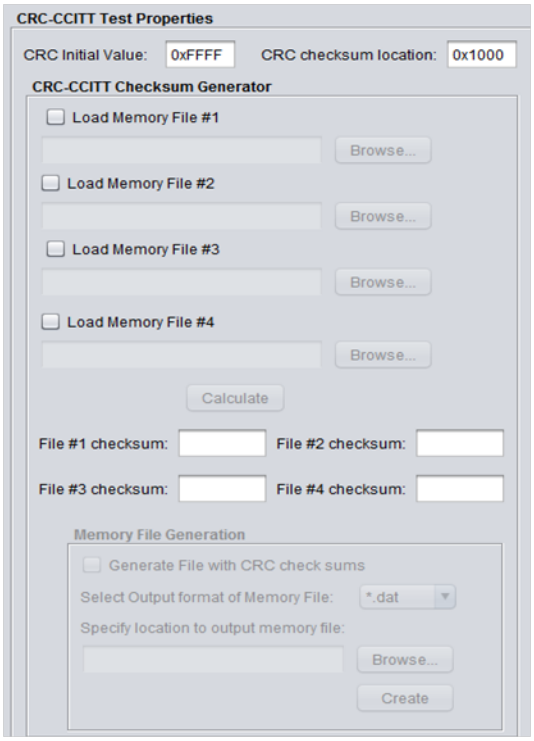


To integrate the custom generated file to the library you must rename “IEC60730_user_config_custom.h" to “IEC60730_user_config.h". Once you rename the file you will be able to run the self test with the custom parameters.

NOTE: It is suggested that the user keeps a copy of the original “IEC60730_user_config.h". Using a custom configuration file may cause example projects to have compilation errors.

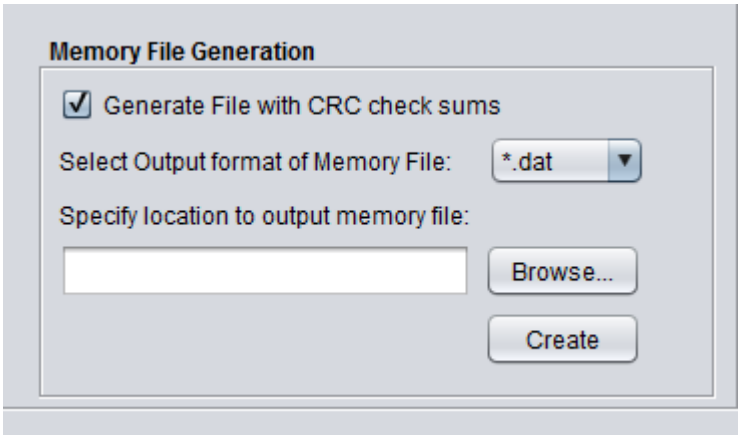
13.5 Generating CRC-CCITT checksum memory file

The MSP430 IEC60730 Software Package Configuration Tool includes a panel that allows users to generate ∗.dat and ∗.txt memory file with CRC-CCITT checksums calculated from memory locations that are monitored by the non-volatile test.

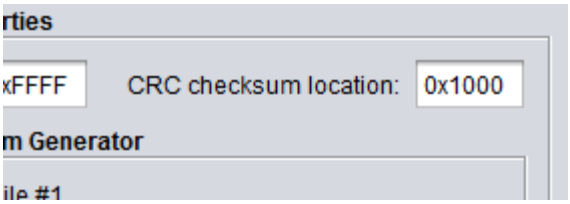


To generate the checksum memory file:

1. Obtain a $*$.dat or $*$.txt file with the memory content to be monitored by the test. To generate the memory file please refer to Obtaining memory file
2. Load the generated file(s) to the configuration tool using the “Load Memory File X" checkboxes.
3. Once you load all the memory files, click on “Calculate". If the files loaded had the expected format, the CRC-CCITT checksum(s) will be calculated and displayed at “File N checksum:" field. The supported formats are:
   - 16-bit C-style ($*$.dat) file or
   - MSP-430 TXT file ($*$.txt)
4. After, the CRC checksum are calculated click on the checkbox “Generate File with CRC checksums".



5. Verify that the “CRC checksum location" fiels has the correct address.



6. Select the desired output format for the memory file. The output file is IDE dependent:
   - For CCS use (∗.dat) file
   - For IAR use (∗.txt) file
7. Select the output path for the memory file.
8. Click “Create".

NOTE: The CRC-CCITT checksum will be placed in the same order as you are loading the memory files starting at the “CRC checksum location" specified in the Configuration Tool (e.g. loading memory file #1 and #2 with CRC checksum loaction= 0x1800, will place checksum for file #1 in memory location 0x1800 and checksum for file #2 will be placed in 0x1802).

13.6 Obtaining memory file

The general steps to obtain a memory content file in CCS are the following:

1. Determine non-volatile memory location in MSP430 device to be monitored.
   - This can be determined using the “Memory Organization" section in the device datasheet.
2. Obtain memory file using CCS or IAR IDE. If you want to use the CRC checksum generation feature, please verify that the memory file has the expected format.
   - For CCS expected format 16-Bit Hex -C Style
   - For IAR expected format msp430-txt

For more information on how to obtain memory content file in CCS please refer to Example obtaining memory file in CCS or for IAR please refer to Example obtaining memory file in IAR.

13.7 Example obtaining memory file in CCS

The following section shows how to obtain the flash memory content of Bank A in a MSP430F5529 in Code Composer Studio.

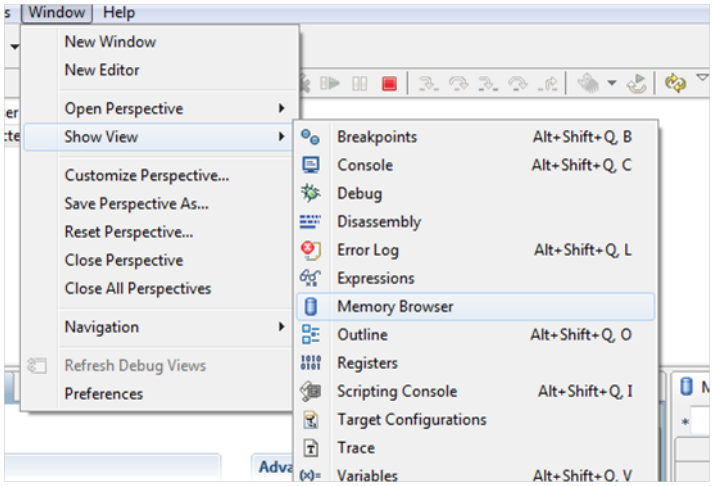
1. Go to “Memory Organization" section in the device datasheet and determine the start and end address for Bank A.

Table 6. Memory Organization(1)

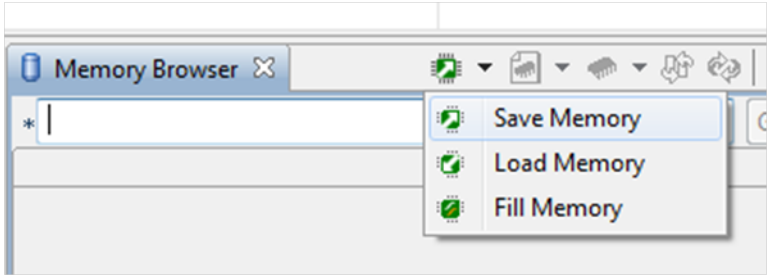
		MSP430F5522 MSP430F5521 MSP430F5513	MSP430F5525 MSP430F5524 MSP430F5515 MSP430F5514	MSP430F5527 MSP430F5526 MSP430F5517	MSP430F5529 MSP430F5528 MSP430F5519
Memory (flash) Main: interrupt vector	Total Size	32 KB 00FFFFh–00FF80h	64 KB 00FFFFh–00FF80h	96 KB 00FFFFh–00FF80h	128 KB 00FFFFh–00FF80h
Main: code memory	Bank D	N/A	N/A	N/A	32 KB 0243FFh–01C400h
	Bank C	N/A	N/A	32 KB 01C3FFh–014400h	32 KB 01C3FFh–014400h
	Bank B	15 KB 00FFFFh–00C400h	32 KB 0143FFh–00C400h	32 KB 0143FFh–00C400h	32 KB 0143FFh–00C400h
	Bank A	17 KB 00C3FFh–008000h	32 KB 00C3FFh–004400h	32 KB 00C3FFh–004400h	32 KB 00C3FFh–004400h
RAM	Sector 3	2 KB(2) 0043FFh–003C00h	N/A	N/A	2 KB 0043FFh–003C00h
	Sector 2	2 KB(3) 003BFFh–003400h	N/A	2 KB 003BFFh–003400h	2 KB 003BFFh–003400h

For MSP430F5529 Bank A has a start address of “0x004400h" and end address of “0x00C3FF".

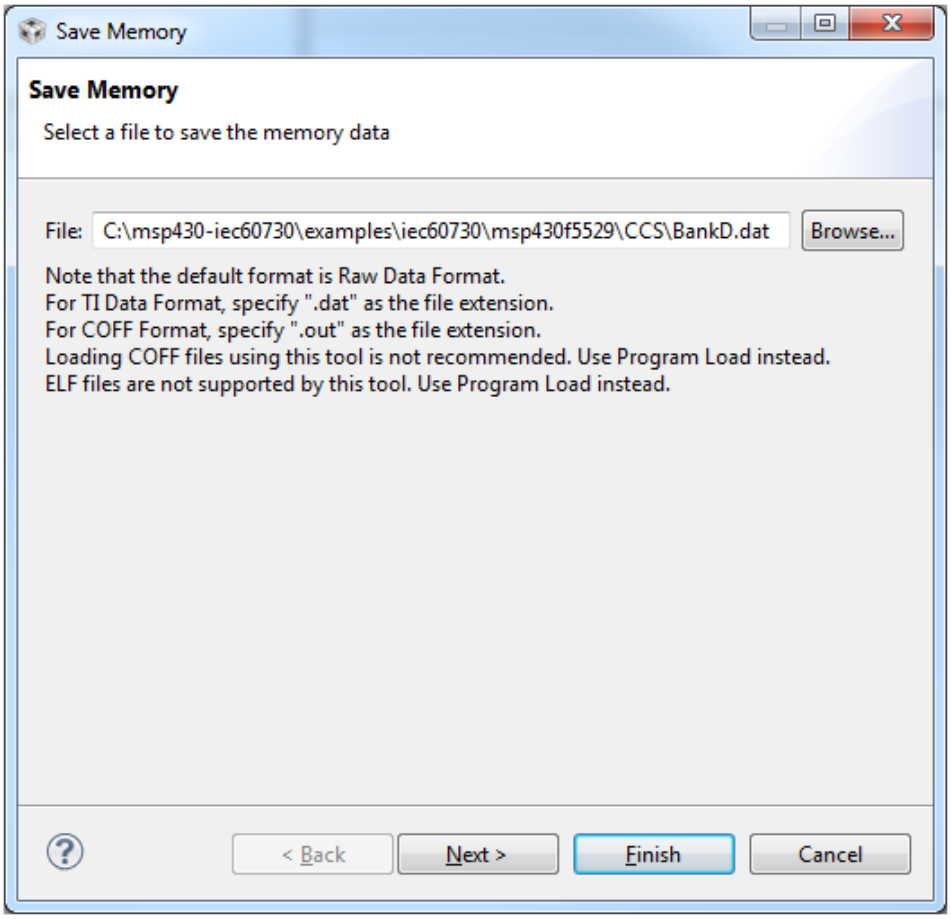
2. Calculate the number of 16-bit word based on the start and end address:
   # of 16-bit words = (end_address - start_address +1)/2
   For this example the “# of 16-bit words = 0x4000"
3. In CCS, start a debugging session of the project.
4. When the debug session has started, go to Windows->Show View->Memory Browser.



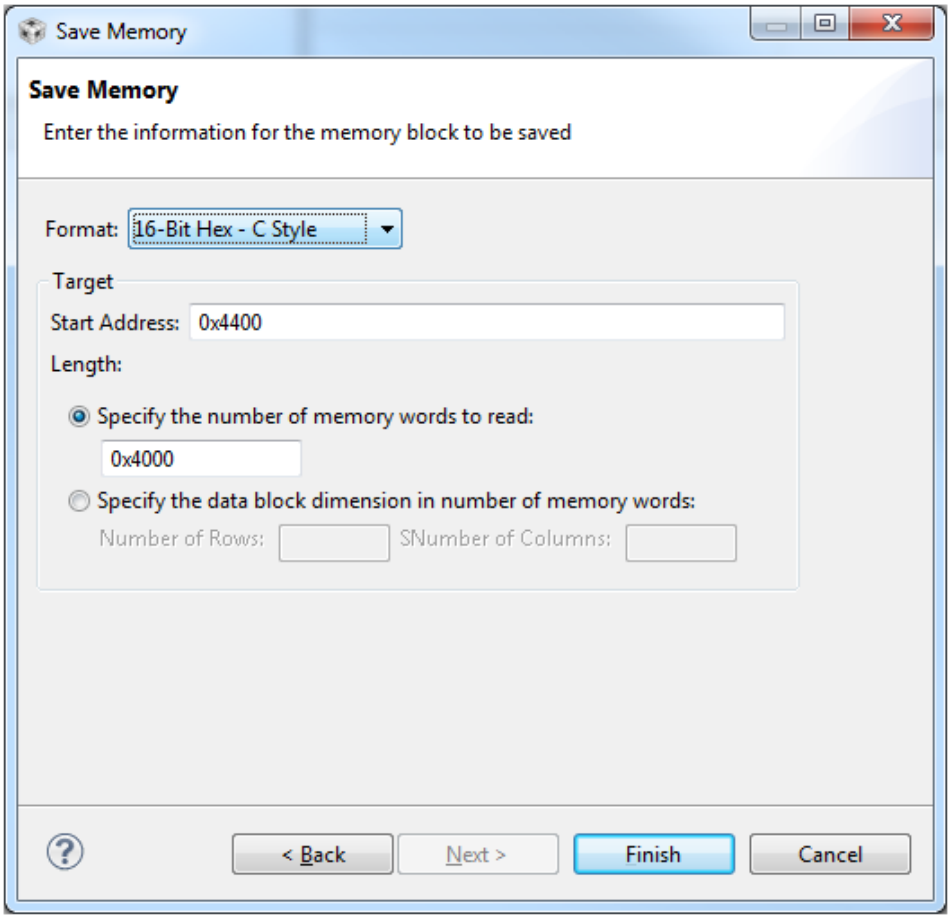
5. In the Memory Browser window select “Save Memory"



6. In the “Save Memory" window select the output path and file name for the memory file. Click “Next"



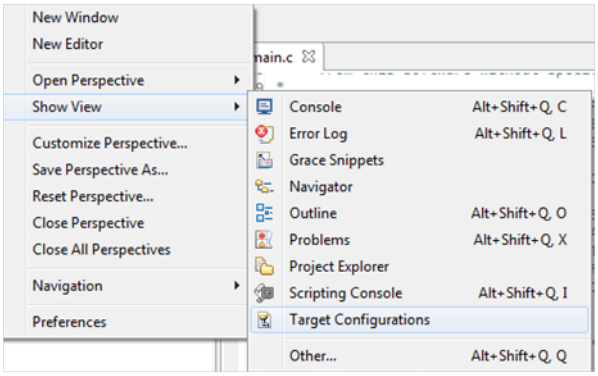
7. Verify “Format" is set to 16-Bit Hex - C Style. Enter “Start Address". Click on “Specify the number of memory words to read" and enter the value calculated in step 2. Click “Finish"



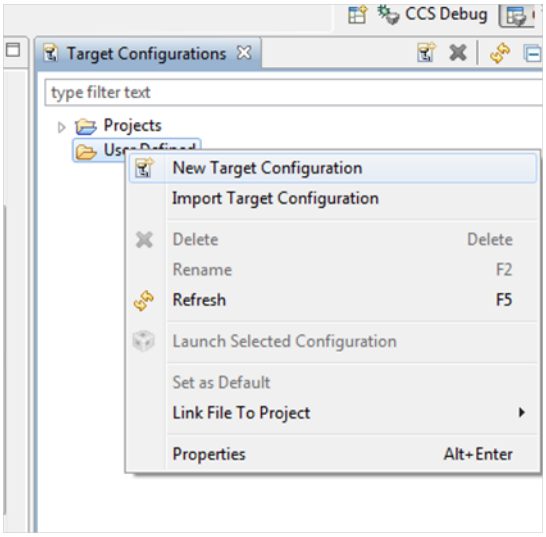
Note:
When generating the memory file verify that no breakpoints are set in the project.

If you currently have no project in CCS and you just want to obtain the memory file. Follow this steps:

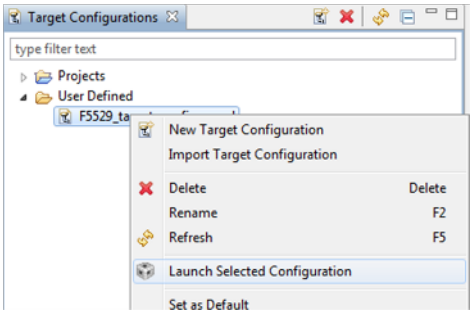
1. In CCS, go to Windows->Show View->Target Configurations



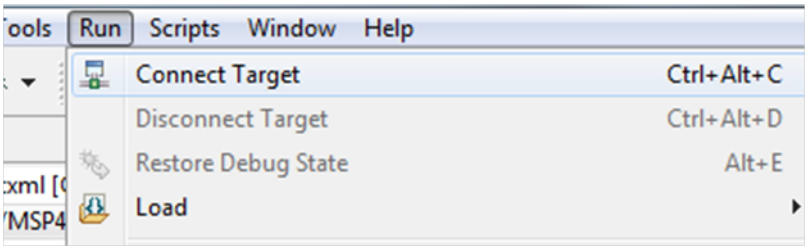
2. In the “Target Configuration" window right-click on “User Defined" and select “New Target Configuration". Type the name of the “Target Configuration". Click “Finish".



3. In the “Target Configuration" window right-click on the new target configuration file you just created and select “Launch Selected Configuration"



4. Once “Debug Perspective" is available, go to Run->Connect Target.



5. Follow Step 4-7 from instructions above.

13.8 Example obtaining memory file in IAR

The following section shows how to obtain the flash memory content of Bank A in a MSP430F5529 in IAR.

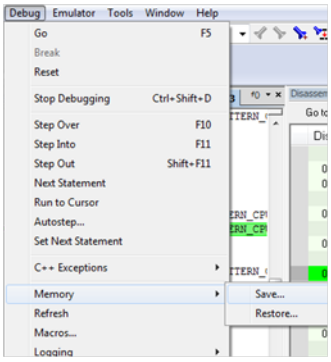
1. Go to “Memory Organization" section in the device datasheet and determine the start and end address for Bank A.

Table 6. Memory Organization(1)

		MSP430F5522 MSP430F5521 MSP430F5513	MSP430F5525 MSP430F5524 MSP430F5515 MSP430F5514	MSP430F5527 MSP430F5526 MSP430F5517	MSP430F5529 MSP430F5528 MSP430F5519
Memory (flash) Main: interrupt vector	Total Size	32 KB 00FFFFh–00FF80h	64 KB 00FFFFh–00FF80h	96 KB 00FFFFh–00FF80h	128 KB 00FFFFh–00FF80h
Main: code memory	Bank D	N/A	N/A	N/A	32 KB 0243FFh–01C400h
	Bank C	N/A	N/A	32 KB 01C3FFh–014400h	32 KB 01C3FFh–014400h
	Bank B	15 KB 00FFFFh–00C400h	32 KB 0143FFh–00C400h	32 KB 0143FFh–00C400h	32 KB 0143FFh–00C400h
	Bank A	17 KB 00C3FFh–008000h	32 KB 00C3FFh–004400h	32 KB 00C3FFh–004400h	32 KB 00C3FFh–004400h
RAM	Sector 3	2 KB(2) 0043FFh–003C00h	N/A	N/A	2 KB 0043FFh–003C00h
	Sector 2	2 KB(3) 003BFFh–003400h	N/A	2 KB 003BFFh–003400h	2 KB 003BFFh–003400h

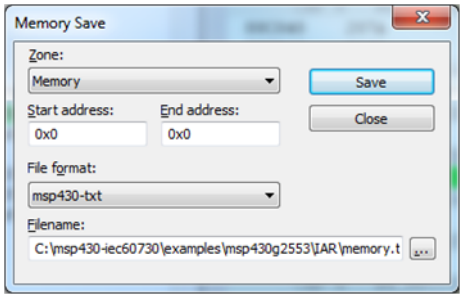
For MSP430F5529 Bank A has a start address of “0x004400" and end address of “0x00C3FF".

2. Start a debugging session in IAR.
3. When the debug session has started in IAR, go to Debug –> Memory –> Save.. .



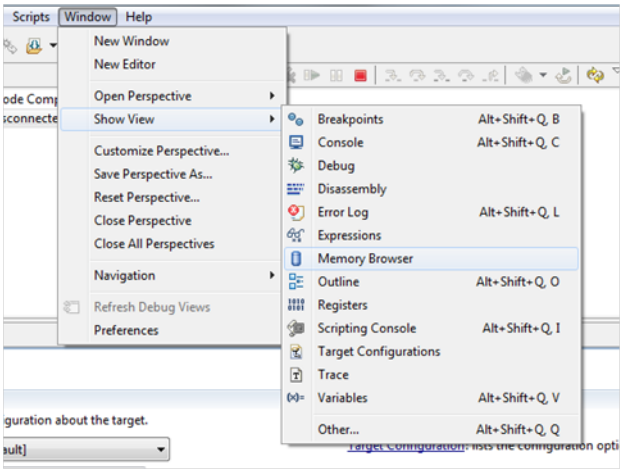
Note:
When generating the memory file verify that no breakpoints are set in the project.

4. In the “Memory Save" window, select “Memory" in the Drop-down menu for “Zone". Type the start and end address. Select “msp430-txt" for File Format. Finally, select the output path and file name of the memory file. Click “Save".

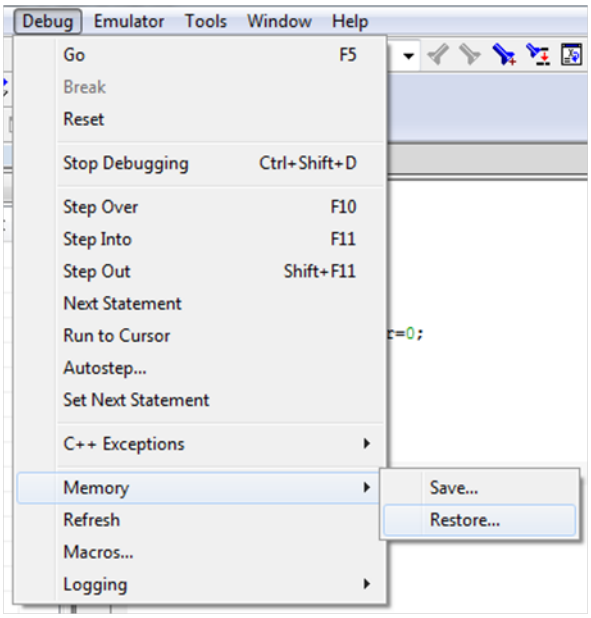


13.9 Loading CRC checksum memory file

To load the memory file in CCS use the “Load Memory" option in the Memory Browser windows. The Memory Browser window can be accessed while debugging an application and selecting Windows–>Show View–>Memory Browser.



To load the memory file in IAR use the “Restore.." memory option while debugging the application. The Restore option is under Debug–>Memory–>Restore.



For detailed step-by-step instruction on how to load the CRC checksums please refer to step 4 and 5 from Generating CRC-CCITT Checksums for examples in CCS or Generating CRC-CCITT Checksums for examples in IAR .

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Broadband	www.ti.com/broadband
DSP	dsp.ti.com	Digital Control	www.ti.com/digitalcontrol
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Military	www.ti.com/military
Logic	logic.ti.com	Optical Networking	www.ti.com/opticalnetwork
Power Mgmt	power.ti.com	Security	www.ti.com/security
Microcontrollers	microcontroller.ti.com	Telephony	www.ti.com/telephony
RFID	www.ti-rfid.com	Video & Imaging	www.ti.com/video
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265