Microchip Class B Safety Software Help

Enhanced Core PIC16F1xxx Family

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1 Introduction

This document describes the Class B Safety Software Library routines that detect the occurrence of Faults in a single channel CPU. These routines have been developed in accordance with the IEC 60730 standard to support the Class B certification process. These routines can be directly integrated with the end user's application to test and verify the critical functionalities of a microcontroller without affecting the end user's application. The Class B Safety Software Library routines can be called at start-up or periodically during run-time to test the following components:

- CPU Registers
- CPU Program Counter
- Invariable Memory
- Variable Memory
- Clock

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3 Getting Started

The folder structure of the Class B Safety Software Library is shown below:

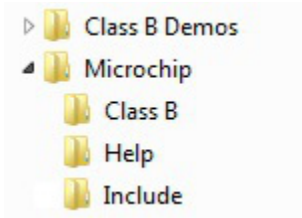

Figure 1: Folder Structure

- The …\Class B Demos folder will contain the library demo projects.
- The …\Microchip folder will contain the library components.
- The …\Class B sub-folder will contain all C files related to the library.
- The …\Help sub-folder will contain this document.
- The …\Include sub-folder will contain all Header files related to the library.

3.1 Class B Library Files

Common	
CLASSB.h	This file contains all of the function declarations for all routines in the library. This file must be included in the main application project.
CLASSB_config.h	This file contains the user-defined configurations for the Class B routines. This file must be included before CLASSB.h in the main application project.
CLASSB_Types.h	This file contains the types used in the library.
CPU Registers	
CLASSB_CPURegistersTest.h	Supporting file for Register test.
CLASSB_CPURegistersTest.c	Routines for CPU Registers test.
CPU Program Counter	
CLASSB_CPUPCTest.h	Supporting file for Program Counter test.
CLASSB_CPUPCTest.c	Routines for CPU Program Counter test.
Invariable Memory	
CLASSB_CRCEEPROMTest.h	Supporting file for EEPROM CRC test.
CLASSB_CRCEEPROMTest.c	Routines for CRC of EEPROM test.
CLASSB_CRCFlashTest.h	Supporting file for Flash CRC test.
CLASSB_CRCFlashTest.c	Routines for CRC of Flash test.
CLASSB_CRCbyte.h	Supporting file for CRC calculation.
CLASSB_CRCbyte.c	Routines for running a single byte through CRC algorithm.
Variable Memory	
CLASSB_RAMCheckerboardTest.h	Supporting file for Checkerboard memory test.
CLASSB_RAMCheckerboardTest.c	Routines for RAM Checkerboard memory test.

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CLASSB_RAMMarchBTest.h	Supporting file for March B memory test.
CLASSB_RAMMarchBTest.c	Routines for RAM March B memory test.
CLASSB_RAMMarchCTest.h	Supporting file for March C memory test.
CLASSB_RAMMarchCTest.c	Routines for RAM March C memory test.
CLASSB_RAMMarchCStackTest.h	Supporting file for March C stack test.
CLASSB_RAMMarchCStackTest.c	Routines for RAM March C stack test.
Clock	
CLASSB_ClockTest.h	Supporting file for Clock accuracy test.
CLASSB_ClockTest.c	Routines for testing CPU clocks against known external clock source.
CLASSB_ClockLineFreqTest.h	Supporting file for Clock accuracy using line frequency test.
CLASSB_ClockLineFreqTest.c	Routines for testing CPU clocks against external line frequency.

3.2 Class B Library Configuration

The Class B Library requires a few user-defined configurations located in CLASSB_config.h. This is where the tests used in the end-user application will be defined, as well as a few part-specific features that will need to be enabled or disabled.

This is shown here:

```
/*****************************************************************************
* CLASSB_DEVICE_FLASH_SIZE_KB
* Defines the size of the flash in K words.
* Used in CLASSB_CPUPCTest
* Valid sizes include: 2, 4, 8, 16
*****************************************************************************/
#define CLASSB_DEVICE_FLASH_SIZE_KB 8


/*****************************************************************************
* MARCHCMINUS
* Defines if user wants to run the MarchCMinus test.
* Used in CLASSB_MarchCTest and CLASSB_MarchCStackTest.
* Comment out to run redundant March C routine.
*****************************************************************************/
#define MARCHCMINUS
```

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```
/*****************************************************************************
* LINE_FREQ_TEST_CCP#
* Defines which CCP register to use for line frequency clock test.
* Used in CLASSB_ClockLineFreqTest
* Default to CCP1
* Please make sure the corresponding TRIS bit is set!
*****************************************************************************/
#define LINE_FREQ_TEST_CCP1
//#define LINE_FREQ_TEST_CCP2
//#define LINE_FREQ_TEST_CCP3
//#define LINE_FREQ_TEST_CCP4
//#define LINE_FREQ_TEST_CCP5


/*****************************************************************************
* CLASSB test function descriptions and enables.
* Default is to enable all tests!
* Comment out each test not used!
*****************************************************************************/
#define CLASSB_MARCHB_TEST_ENABLED
#define CLASSB_MARCHC_TEST_ENABLED
#define CLASSB_MARCHC_STACK_TEST_ENABLED
#define CLASSB_CHECKER_TEST_ENABLED
#define CLASSB_CRCFLASH_TEST_ENABLED
#define CLASSB_CRCEEPROM_TEST_ENABLED
#define CLASSB_CPUREG_TEST_ENABLED
#define CLASSB_CPUPC_TEST_ENABLED
#define CLASSB_LINE_TEST_ENABLED
#define CLASSB_CLOCK_TEST_ENABLED
```

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3.3 Class B Library Memory Usage and Tests Execution Time

PRO Compiler (XC8 v1.12)					
Function:	**# tested**	**Cycles**	**Time**	**RAM(bytes)**	**FLASH(words)**
MarchB	80 bytes	97958	24.4895 ms	19	609
MarchC	80 bytes	99080	24.77 ms	8	641
MarchCMinus	80 bytes	85912	21.478 ms	NA	564
MarchCStack	NA	1364	341 us	1	341
Checkerboard	8 bytes	1275	318.75 us	11	114
CRC Flash	8K addresses	901164	56.323 ms	14	63
CRC EEPROM	254 addresses	16804	4.201 ms	9	57
CRC_byte	NA	NA	NA	2	28
CPU Registers	6 registers	106	26.5 us	0	96
CPU PC	NA	34	8.5 us	0	22
Clock_LineFreq	NA	NA	1 s	47	355
Clock	NA	NA	USER	35	325

Total (allTestsDemo) - MarchCMinus		
Time	**RAM**	**FLASH**
1.307 s	160	2988

Notes:
1. Processor speed is 16 MHz.
2. All times are estimates based on the MPLABX simulator.
3. All RAM and FLASH usage is test-only (does not include main file).
4. RAM usage is estimated based on MAP file.

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4 Class B Library API

This section describes the Class B Library API. The API is setup so that all test functions either return the related information or an industry standard 0 for pass, 1 for fail. This is handled in the CLASSB_Types.h header file and described below.

The function definitions are listed here and described in greater detail below:

- `CLASSBRESULT CLASSB_CPURegistersTest();`
- `CLASSBRESULT CLASSB_CPUPCTest();`
- `uint16_t CLASSB_CRCEEPROMTest(uint8_t startAddress, size_t length, uint16_t crcSeed);`
- `uint16_t CLASSB_CRCFlashTest(uint16_t startAddress, uint16_t length, uint16_t crcSeed);`
- `CLASSBRESULT CLASSB_RAMCheckerboardTest(uint8_t* startAddress, uint8_t length, uint8_t* bufferAddress);`
- `CLASSBRESULT CLASSB_RAMMarchBTest();`
- `CLASSBRESULT CLASSB_RAMMarchCTest();`
- `CLASSBRESULT CLASSB_RAMMarchCStackTest();`
- `CLASSBRESULT CLASSB_ClockTest(uint32_t clockFrequency, uint32_t referenceFrequency, size_t msec, uint8_t tolerance);`
- `void CLASSB_ClockLineFreqTest(uint32_t clockFrequency, uint8_t lineFrequency, uint8_t tolerance);`

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4.1 CLASSBRESULT

Enumeration:
CLASSBRESULT

Description:
This enumeration is used by the class B test functions to return the results:

CLASSB_TEST_PASS = 0	-	the test finished successfully,
CLASSB_TEST_FAIL	-	the test is failed,
CLASSB_TEST_TIMEOUT	-	the test is failed because a timeout was detected,
CLASSB_TEST_INPROGRESS	-	the test is still in progress.

4.2 CPU Registers Test

Function:
CLASSBRESULT CLASSB_CPURegistersTest()

Description:
Tests CPU registers.

Precondition:
Interrupts must be disabled.

Parameters:
None.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
Interrupts must be disabled during the test.
Only CPU specific registers are tested.
Peripheral registers are not tested.

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4.3 CPU Program Counter Test

Function:
CLASSBRESULT CLASSB_CPUPCTest()

Description:
Tests CPU program counter.

Precondition:
None.

Parameters:
None.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
The device flash memory size must be set using parameter CLASSB_DEVICE_FLASH_SIZE in CLASSB_config.h.

4.4 EEPROM CRC Test

Function:
uint16_t CLASSB_CRCEEPROMTest(startAddress, length, crcSeed)

Description:
Tests the EEPROM memory using the Cyclic Redundancy Check (CRC).

Parameters:

startAddress	-	the first address of the tested EEPROM memory.
length	-	the number of EEPROM locations tested.
crcSeed	-	the initial value of the CRC calculation.

Returns:
Returns the final CRC result.

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4.5 Flash CRC Test

Function:
uint16_t CLASSB_CRCFlashTest(startAddress, length, crcSeed)

Description:
Tests the flash memory using the Cyclic Redundancy Check (CRC).

Parameters:
startAddress - the first address of the tested flash memory.
Length - the number of flash locations tested.
crcSeed - the initial value of the CRC calculation.

Returns:
Returns the final CRC result.

4.6 RAM Checkerboard Test

Function:
CLASSBRESULT CLASSB_RAMCheckerboardTest(startAddress, length, bufferAddress)

Description:
Tests the RAM memory region using checker board pattern.

Precondition:
Interrupts must be disabled.

Parameters:
startAddress - the first address of the tested RAM memory,
length - the byte length of the tested RAM memory,
bufferAddress - the first address of the RAM memory to save user data.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
The length must be even.
Interrupts must be disabled during the test.

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4.7 RAM March B Test

Function:
CLASSBRESULT CLASSB_RAMMarchBTest()

Summary:
Tests the RAM memory using March B algorithm.

Precondition:
Interrupts must be disabled.

Parameters:

CLASSB_MarchstartAddress	- the first address of the tested RAM memory,
CLASSB_MarchLength	- the byte length of the tested RAM memory.
CLASSB_MarchbufferAddress	- the first address of the location in RAM to save user data

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
Interrupts must be disabled during the test.
If CLASSB_MarchbufferAddress is NULL the test is destructive.
The test uses 7 bytes of RAM for global variables used in test.

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4.8 RAM March C Test

Function:
CLASSBRESULT CLASSB_RAMMarchCTest()

Description:
Tests the RAM memory region using March C algorithm.

Precondition:
Interrupts must be disabled.

Parameters:

CLASSB_MarchstartAddress	- the first address of the tested RAM memory,
CLASSB_MarchLength	- the byte length of the tested RAM memory.
CLASSB_MarchbufferAddress	- the first address of the location in RAM to save user data
MARCHCMINUS	- if the parameter is TRUE the "minus" algorithm is used.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
Interrupts must be disabled during the test.
If bufferAddress is NULL the test is destructive.
The test uses 7 bytes of RAM for global variables used in test.

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4.9 RAM March C Stack Test

Function:
CLASSBRESULT CLASSB_RAMMarchCStackTest()

Description:
Tests the RAM memory region associated with the stack using March C algorithm.

Precondition:
Interrupts must be disabled.

Parameters:

CLASSB_MarchstartAddress	- the first address of the tested RAM memory,
CLASSB_MarchLength	- the byte length of the tested RAM memory.
CLASSB_MarchbufferAddress	- the first address of the location in RAM to save user data
MARCHCMINUS	- if the parameter is TRUE the "minus" algorithm is used.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
Interrupts must be disabled during the test.
To run the stack test a minimum of 33 bytes must be allocated for the bufferAddress.

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4.10 Clock Test

Function:
CLASSBRESULT CLASSB_ClockTest(clockFrequency, referenceFrequency, msec, tolerance)

Summary:
Tests the system clock using an external crystal into Timer1.

Precondition:
An external oscillator is connected to Timer1.

Parameters:

clockFrequency	- system clock frequency.
referenceFrequency	- reference clock frequency.
msec	- the time in milliseconds to run the test.
tolerance	- the tolerance level of the system oscillator.

Returns:
Returns zero if successful. Non zero means - failed.

Remarks:
Recommend a 20 ms test time for best results.
Will not work with a reference frequency higher than 2MHz.

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4.11 Clock Line Frequency Test

Function:
void CLASSB_ClockLineFreqTest(clockFrequency, lineFrequency, tolerance)

Summary:
Tests the system clock using the line frequency into the Capture Module (CCP).

Precondition:
Zero Cross detection circuit is the input to one of the CCP inputs.

Parameters:
clockFrequency - system clock frequency.
referenceFrequency - reference clock frequency.
tolerance - the tolerance level of the system oscillator.

Returns:
None

Result:
The result of this test can be accessed two ways:
1. Through a Function pointer declared above as *ClockLineFreqTestFail or...
2. Using the ClockLineFreqTestFlag which will follow the definition of CLASSBRESULT

Remarks:
This is a timing critical test.
Changes to TMR1 during the progress of this test will cause the test to fail.
This test takes one second.

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5 Using the API

The Class B Library does not require modifications of the linker script to help to ensure compatibility with end-user applications. To use the library functions, the header files CLASSB_config.h and CLASSB.h must be included in the application source file. Unless otherwise stated, interrupts must be disabled during the Class B Library tests. Failure to disable interrupts can result in memory corruption and false results from the tests.

The following information will help guide the user through the process of adding the Class B Library tests to the end application:

- Typical application flow chart using Class B functions.
- Useful MPLABX Tools.
- Code examples for using the Class B functions.

5.1 Application Flow Chart

The following is a typical application flow chart using the Class B Library functions. This shows an application like motor control with minimal interruptions for Class B testing. Some functions can be called periodically during normal run-time without interrupting the normal flow of the application significantly. Other functions take significantly longer and should be run only at start-up or in small chunks.

It is important to note that in most cases it is not necessary to run both the March B and March C tests, only one needs to be chosen.

The clock test that best fits the application should be chosen. If the application already has access to a zero-cross detection circuit, the ClockLineFreqTest can be chosen without interfering greatly with the overall circuit. The ClockTest requires an external clock source on Timer 1.

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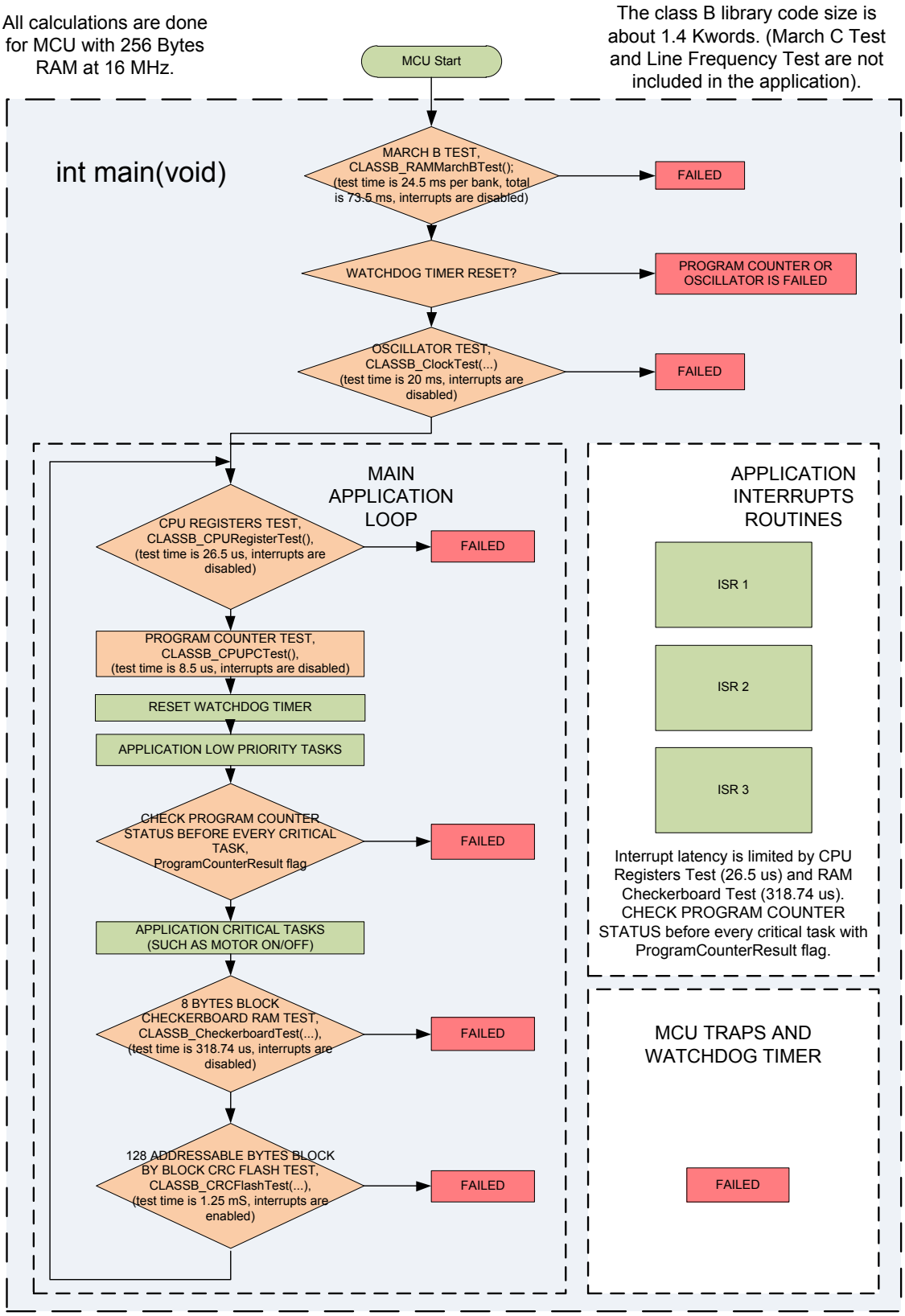

Figure 2: Application Flow Chart

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5.2 MPLABX Tools

In MPLABX, there are a few useful tools that can be quite helpful for developing an application with the Class B Library.

One such tool is the MAP file. The MAP file will indicate the used memory regions (the start address and length). The MAP file's default location is:

…\ApplicationProject.X\dist\default\production

The other useful tool for developing Class B applications is the stopwatch. The stopwatch can give the user important information about the specific timing requirements for the application. This will define when the Class B functions can be called.

The location of the Stopwatch is shown here:

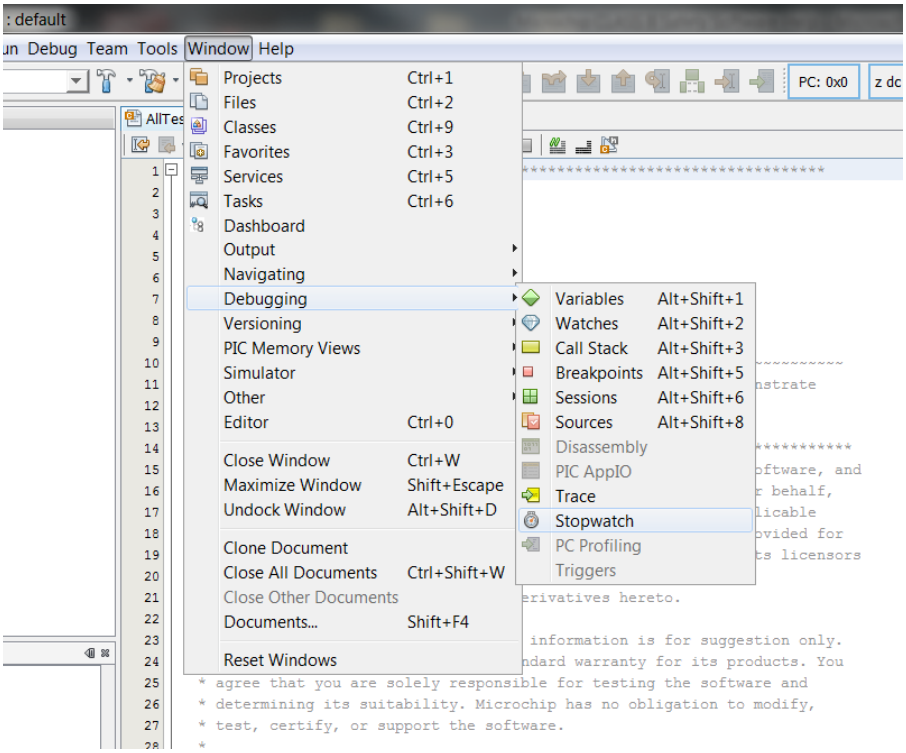

Figure 3: Stopwatch

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5.3 Code Examples

All code examples can also be found in AllTestsMain.c in CLASSB_AllTestsDemo.X.

```
/**************************************************************************
*   Program Counter Test.
**************************************************************************/
    CLASSBRESULT  ProgramCounterResult = CLASSB_TEST_INPROGRESS;
    ProgramCounterResult = CLASSB_CPUPCTest();

    if (ProgramCounterResult == CLASSB_TEST_PASS)
    {
        asm("nop");           /* Test pass */
    }
    else
    {
        ErrorMode();          /* Test not pass */
    }



/**************************************************************************
*   CPU Registers Test.
**************************************************************************/
    //Do a check to see if the Program Counter did not error.
    if (ProgramCounterResult == CLASSB_TEST_INPROGRESS)
        ErrorMode();

    testResult = CLASSB_CPURegistersTest();

    if (testResult == CLASSB_TEST_PASS)
    {
        asm("nop");           /* Test pass */
    }
    else
    {
        ErrorMode();          /* Test not pass */
    }
```

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```
/*****************************************************************************
*   Clock Test.
*****************************************************************************/
    uint32_t clockFrequency = 16000000; //system clock: 16MHz
    uint32_t referenceFrequency = 32768; //reference clock: 32.768kHz
    uint8_t msec = 20; //Test time: 20ms
    uint8_t tolerance = 5; //Tolerance level: 5%

    testResult = CLASSB_ClockTest(clockFrequency, referenceFrequency, msec,
      tolerance);

    if (testResult == CLASSB_TEST_PASS)
    {
        asm("nop");     /* Test pass */
    }
    else
    {
        ErrorMode();    /* Test not pass */
    }


/*****************************************************************************
*   Clock Line Frequency Test.
*****************************************************************************/
    uint32_t clockFrequency = 16000000; //system clock: 16MHz
    uint32_t lineFrequency = 60; //reference clock: 60Hz zero-cross
    uint8_t tolerance = 5; //Tolerance level: 5%

    CLASSB_ClockLineFreqTest(clockFrequency, lineFrequency, tolerance);

    //For this demo the code will wait for the test to finish.
    //In application, code can be placed here as long as it is ok to be
    //interrupted!
    while (ClockLineFreqTestFlag == CLASSB_TEST_INPROGRESS);

    if (ClockLineFreqTestFlag == CLASSB_TEST_PASS)
    {
        asm("nop");     /* Test pass */
    }
    else
    {
        ErrorMode();    /* Test not pass */
    }
```

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```
/*****************************************************************************
*   March B Test. (This example tests BANK 0)
*****************************************************************************/
    CLASSB_MarchstartAddress = (char*)0x20;
    CLASSB_MarchbufferAddress = (char*)0xB0;
    CLASSB_MarchLength = 0x50;

    testResult = CLASSB_RAMMarchBTest();

    if (testResult==CLASSB_TEST_PASS)
    {
        asm("nop");      /* Test pass */
    }
    else
    {
        ErrorMode();     /* Test not pass */
    }


/*****************************************************************************
*   March C Test. (This example tests Bank 0)
*****************************************************************************/
    CLASSB_MarchstartAddress = (char*)0x20;
    CLASSB_MarchbufferAddress = (char*)0xB0;
    CLASSB_MarchLength = 0x50;

    testResult = CLASSB_RAMMarchCTest();

    if (testResult==CLASSB_TEST_PASS)
    {
        asm("nop");      /* Test pass */
    }
    else
    {
        ErrorMode();     /* Test not pass */
    }
```

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```
/*****************************************************************************
*   March C Stack Test.
*****************************************************************************/
    CLASSB_MarchbufferAddress = (char*)0x27;
    CLASSB_MarchLength = 33;

    testResult = CLASSB_RAMMarchCStackTest();

    if (testResult==CLASSB_TEST_PASS)
    {
        asm("nop");     /* Test pass */
    }
    else
    {
        ErrorMode();    /* Test not pass */
    }

/*****************************************************************************
*   Initial EEPROM CRC test.
*****************************************************************************/
    uint8_t EEPROMAddress = 0x01;
    uint8_t length = 254;
    uint16_t crcSeed = 0xFFFF;
    volatile unsigned int CLASSB_EEPROMtestResult;

    CLASSB_EEPROMtestResult = CLASSB_CRCEEPROMTest(EEPROMAddress, length,
      crcSeed);

/*****************************************************************************
*   Initial Flash CRC test.
*****************************************************************************/
    uint16_t FlashAddress = 0x00;
    uint16_t Flashlength = 0x2000;
    crcSeed = 0xFFFF;
    volatile unsigned int CLASSB_FlashtestResult;

    CLASSB_FlashtestResult = CLASSB_CRCFlashTest(FlashAddress, Flashlength,
      crcSeed);

//The Check Values for the Flash and EEPROM can now be saved for future
//comparison or compared to a known constant, depending on the application
```

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```
/*****************************************************************************
*   Checkerboard Test
*****************************************************************************/
    uint8_t* CheckerStartAddress;
    uint8_t* CheckerBufferAddress;
    uint8_t CheckerLength;

//In this example we show the checkerboard test used on RAM locations
//0x50 - 0x57. The Checkerboard should be used as a faster alternative
//to the March Tests during run-time. Safety specific RAM locations
//should be tested with this method.
    CheckerStartAddress = (char*)0x50;
    CheckerBufferAddress = (char*)0x58;
    CheckerLength = 8;

    testResult = CLASSB_RAMCheckerboardTest(CheckerStartAddress,
      CheckerLength, CheckerBufferAddress);

    if (testResult==CLASSB_TEST_PASS)
    {
        asm("nop");     /* Test pass */
    }
    else
    {
        ErrorMode();    /* Test not pass */
    }
```

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6 Resources

To get more information about the Class B Safety Software Library visit:

http://www.microchip.com/pagehandler/en-us/technology/homeAppliance/classbsafetysoftware.html

The following Articles are also available:

- AN1229 – Class B Safety Software Library for PIC® MCUs and dsPIC® DSCs
- Future AN - Using Hardware or Software CRC with Enhanced Core PIC16F1xxx in Class B Applications

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7 Revision History

4/10/2014…….First release of Help File.

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