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## MPLAB Code Coverage User's Guide

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### Notice to Customers

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**Important:**

All documentation becomes dated and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website ([www.microchip.com](http://www.microchip.com)) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA," where "XXXXX" is the document number and "A" is the alphabetic revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Help Content to open a list of available online help files.

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# 1. MPLAB Code Coverage Overview

The MPLAB® Code Coverage feature provides visibility as to what portions of your code are being executed. Run your test cases to completion for a visual display of coverage.

The MPLAB Code Coverage feature requires the following tools:

- An MPLAB XC C compiler, either Free or PRO, that supports code coverage output, starting with MPLAB XC8 v2.10, MPLAB XC16 v1.40, and MPLAB XC32 v2.30.
- The MPLAB Code Coverage (SW006026-COV) license that provides visibility as to what portions of your code are being executed.
- MPLAB X IDE v5.25 or later, which supports the display of code coverage data from an MPLAB XC C compiler with the MPLAB Code Coverage license.

**Note:** This manual is written for MPLAB X IDE v5.30 or later.

**Note:** Code coverage visibility is not available on the command line; you must use MPLAB X IDE.

Code coverage is displayed in the MPLAB X IDE as:

- Editor text highlighted by colors representing coverage: green = executed, yellow = partially executed, and red = not executed.
- Program memory highlighted by colors representing coverage.
- A Code Coverage tab with a report displaying color percentages of code covered. This information may be written to an HTML Report for later viewing.

**Figure 1-1. Code Coverage - Editor Window and Code Coverage Tab**

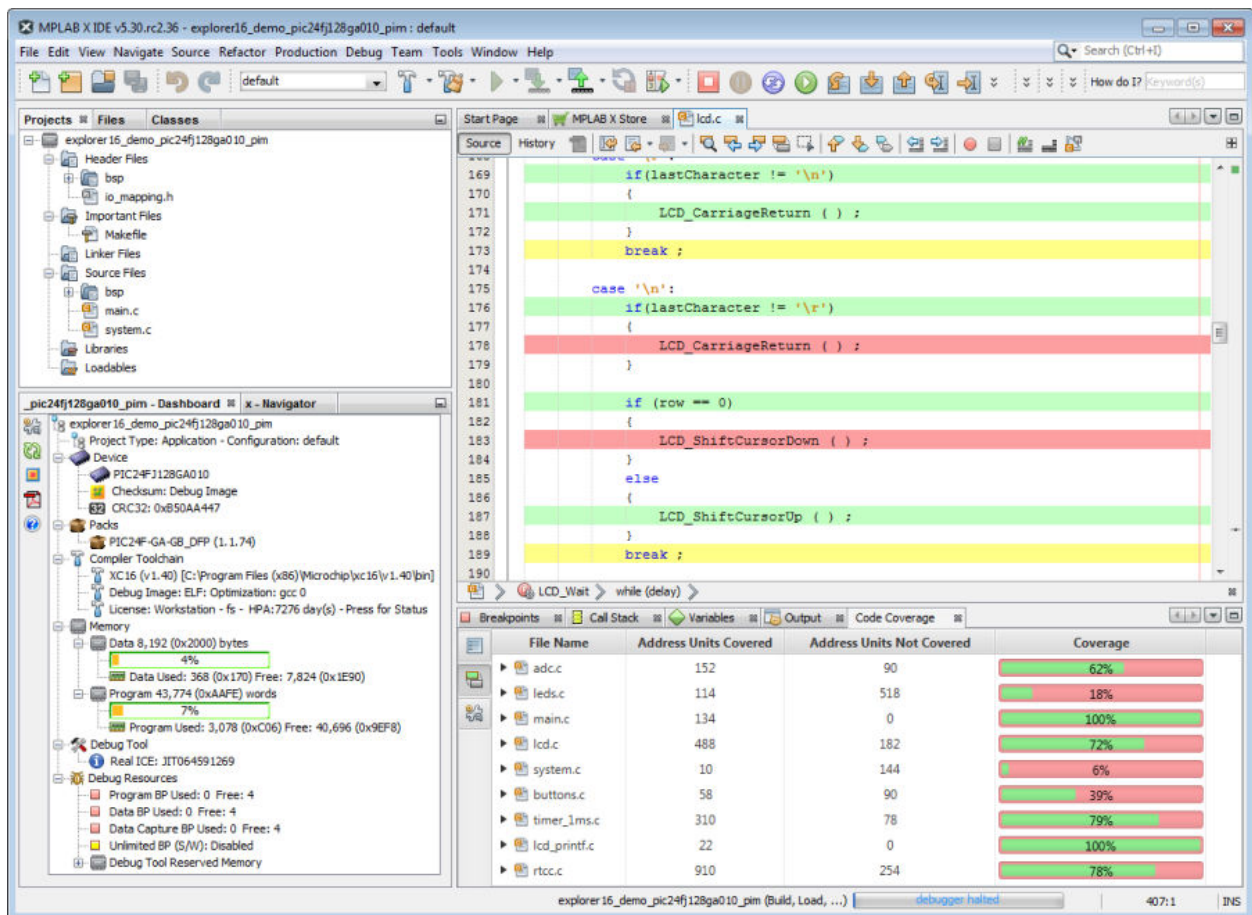


Figure 1-2. Figure 2. Code Coverage - Program Memory Window

Line	Address	Opcode	Label	DisAssy
2,900	016A6	320006		BRA Z, .L63, .L71
2,901	016A8	500FE5		SUB W0, #0x5, [W15]
2,902	016AA	3A0008		BRA NZ, .L66, .L72
2,903	016AC	A8A869		BSET 0x869, #5
2,904	016AE	A9A32C		BCLR AD1PCFG, #5
2,905	016B0	B3C010		MOV.B #0x1, W0
2,906	016B2	370006		BRA .L65, .L73
2,907	016B4	A8E869		BSET 0x869, #7
2,908	016B6	A9832C		BCLR AD1PCFG, #4
2,909	016B8	B3C010		MOV.B #0x1, W0
2,910	016BA	370002		BRA .L65, .L73
2,911	016BC	A8C869		BSET 0x869, #6
2,912	016BE	EB4000		CLR.B W0

Memory: Program Memory      Format: Code

### 2. MPLAB Code Coverage Details

Use the MPLAB Code Coverage license with MPLAB XC C compiler and MPLAB X IDE versions that support code coverage to view code coverage output.

MPLAB Code Coverage works with anything built from C source code.

MPLAB Code Coverage is supported on any debug tool supported by MPLAB X IDE.

#### Compiler Operation

Code coverage is supported by MPLAB XC C compiler instrumentation. The compiler adds a minimal amount of code in program memory to update flags in RAM to indicate coverage.

#### MPLAB X IDE Operation

The IDE will display highlighted covered code and percentages of covered code for project files. You may select which files to include for coverage by setting up file properties. See [6.2.3 Code Coverage by Project File](#).

A report of the coverage may be generated also. See [7. Create a Code Coverage HTML Report](#).

### 3. Get the Software

To use code coverage, you will need to acquire the following tools.

#### **MPLAB X IDE**

MPLAB X IDE support for viewing code coverage output began with version v5.25, with additional features added in v5.30.

The IDE may be downloaded for free at <https://www.microchip.com/mplab/mplab-x-ide>.

#### **MPLAB XC C Compilers**

The MPLAB Code Coverage license may be used with MPLAB XC C compilers (Free and PRO) that support code coverage, beginning with the following versions:

- MPLAB XC8 v2.10
- MPLAB XC16 v1.40
- MPLAB XC32 v2.30

MPLAB XC C compilers may be downloaded at <https://www.microchip.com/mplab/compilers>.

#### **MPLAB Code Coverage License**

An MPLAB Code Coverage (SW006026-COV) license may be purchased and activated like other compiler licenses. For more information, see *"Installing and Licensing MPLAB<sup>®</sup> XC C Compilers"* (DS50002059) for details.

See also <http://www.microchip.com/mplab/codecoverage>.

This license is for one (1) computer/workstation only (not Networks). However, it will work for all MPLAB XC C compilers on that computer. This license may be used with Free and PRO compilers.

## 4. Enable/Disable Code Coverage

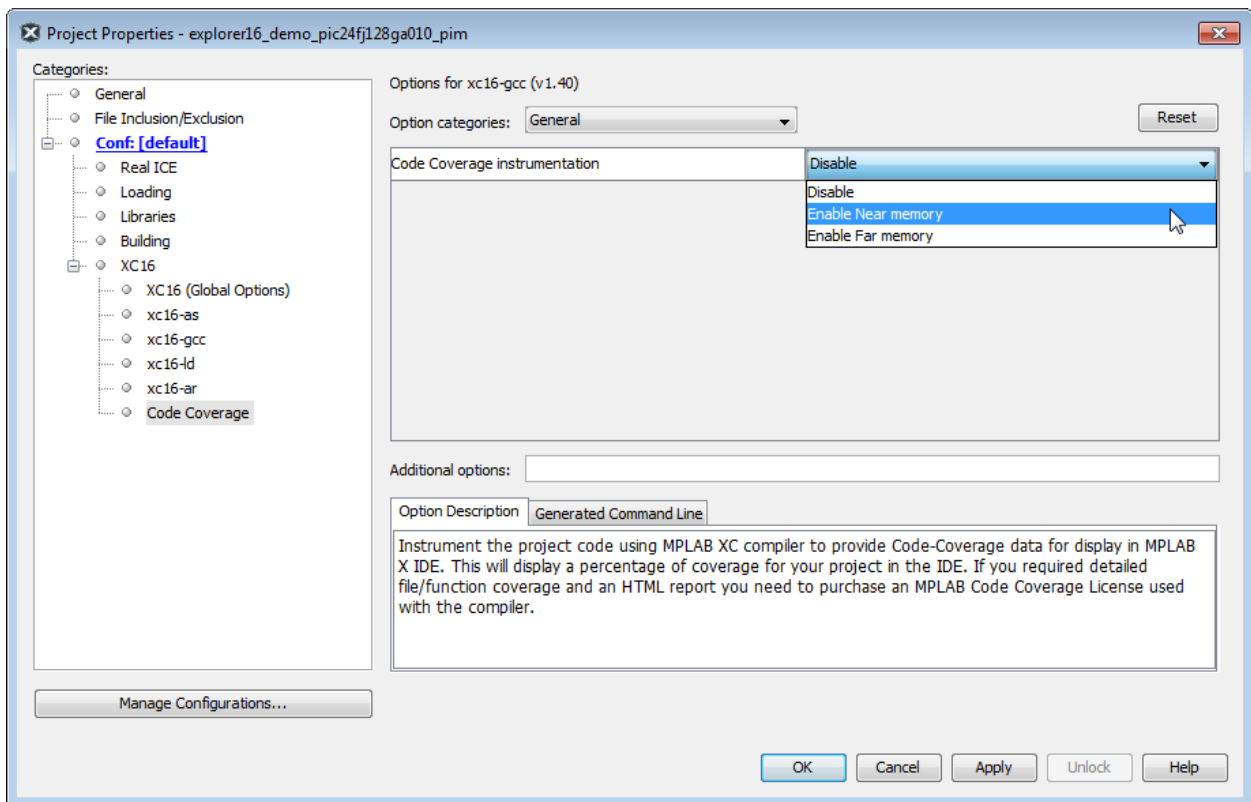
By default, MPLAB Code Coverage is disabled. To enable code coverage, complete the following steps:

1. Right click on the name of your project in the Projects window and select “Properties.”
2. Under “Categories,” find the project compiler, i.e., XC $nn$ , where  $nn$  is either 8, 16 or 32.
3. Click on the “Code Coverage” under the compiler (see figure).
4. Select “Code Coverage Instrumentation.” Selections differ for each MPLAB XC compiler. See the table below.

**Table 4-1. Enable Code Coverage Options by Compiler**

MPLAB XC C Compiler	Enable Options	Description
XC8	Disable	Disable code coverage.
	Enable	Enable code coverage.
XC16	Disable	Disable code coverage.
	Enable Near memory	Use Near RAM space for code coverage instrumentation ( <b>recommended</b> ). If there is a link error, then select Far.
	Enable Far memory	Use Far RAM space for code coverage instrumentation.
XC32	Disable	Disable code coverage.
	Enable	Enable code coverage.

**Figure 4-1. Code Coverage Options - MPLAB XC16 Example**



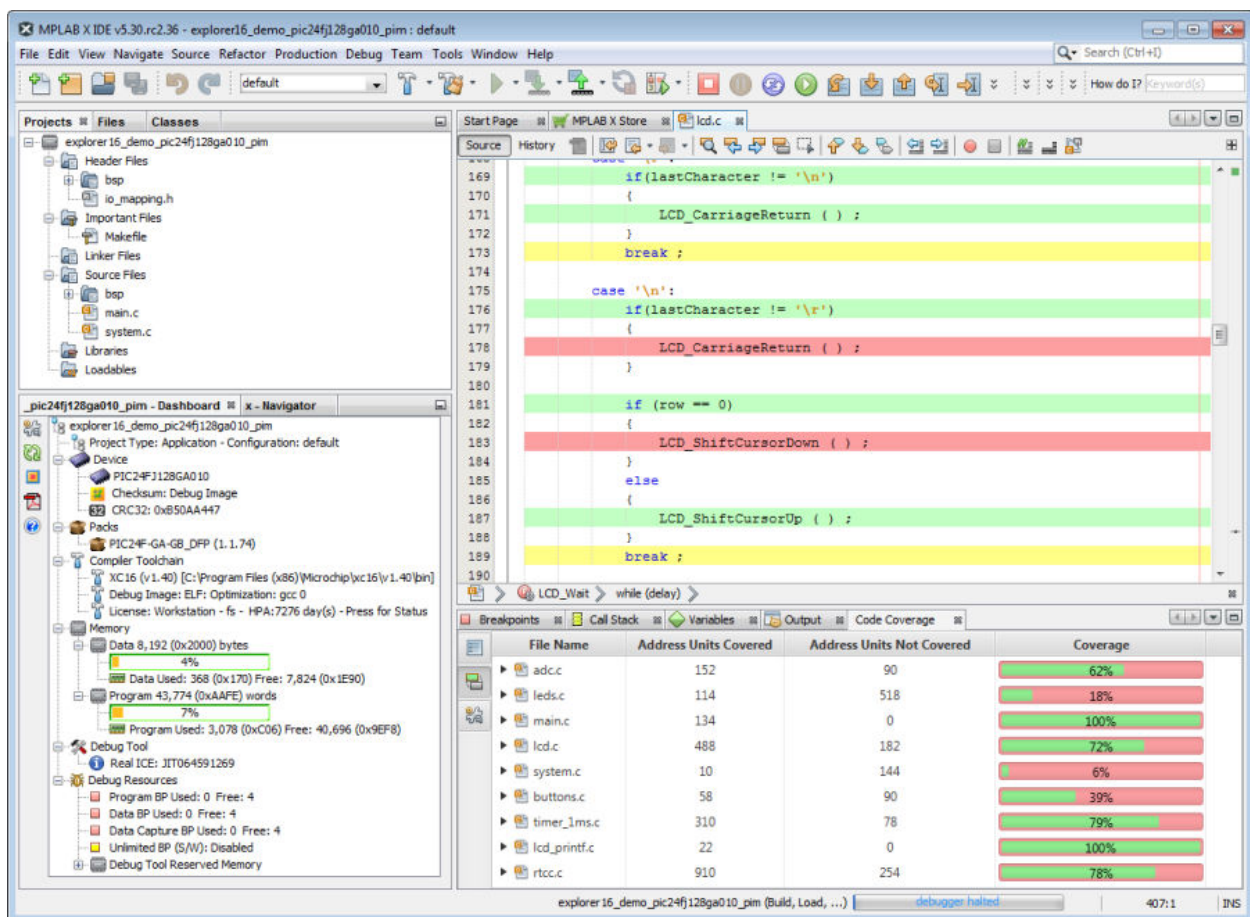
## 5. View Code Coverage Output

After you have enabled code coverage, as described in 4. [Enable/Disable Code Coverage](#), debug your code and execute all test cases to completion. Then halt execution automatically or manually and step as needed till all code execution is complete.

To view code coverage:

- Right click on project name and select “Show Code Coverage Summary” or select *Window>Debugging>Code Coverage*.
- To see highlight in Editor window you may need to click in it. Covered code will be highlighted in the window.
- To see highlight in Program (or Execution) Memory window, open it under *Windows>Target Memory Views*. Covered instructions will be highlighted in the window.
- A summary report will be shown in the Code Coverage tab.

Figure 5-1. Code Coverage in MPLAB X IDE





### 5.1 Highlight Colors

The meaning of highlight colors in the Editor window and Program or Execution Memory window are described in the table below.

Highlight Color	Highlight Name	Meaning
	Green	Covered and Executed



.....continued		
Highlight Color	Highlight Name	Meaning
	Yellow	Covered and Partially Executed (Editor window only)
	Red	Covered but not Executed
	No Color	No coverage information generated <sup>1</sup>

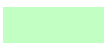

**Note 1:** Reasons why no coverage information would be generated include:

- Some C constructions may not generate code for a C source line
- Optimizations may cause code not to be generated for a C source line

There may be other circumstances that C source lines do not produce executable code. See the examples in [6. Understand Code Coverage Output](#).

## 5.2 Coverage Colors




On the Code Coverage tab, the colors on the bar chart under “Coverage” have the following meanings:

Coverage Color	Coverage Name	Meaning
	Green	Total code covered and executed by test suite(s).
	Red	Total code covered by test suite(s).

For more on this tab, see [6.1.2 Code Coverage Window](#).

## 5.3 Code Coverage Tab Buttons

Click on buttons in the gutter of this tab for the following functions.

	Generate HTML Report. This report will show the same data presented in the Code Coverage window.
	Toggle (enable/disable) color highlighting in editor window.
	Open Project Properties to enable/disable code coverage.

## 6. Understand Code Coverage Output

The following sections detail what the different IDE displays are showing you about code coverage.

### 6.1 Demo Code Example

Figure 6-1. Editor Window - Demo Code Example

```

169     if(lastCharacter != '\n')
170     {
171         LCD_CarriageReturn ( ) ;
172     }
173     break ;
174
175     case '\n':
176     if(lastCharacter != '\r')
177     {
178         LCD_CarriageReturn ( ) ;
179     }
180
181     if (row == 0)
182     {
183         LCD_ShiftCursorDown ( ) ;
184     }
185     else
186     {
187         LCD_ShiftCursorUp ( ) ;
188     }
189     break ;
190

```

The Explorer 16/32 Board Demo Code for a PIC24FJ128GA010 PIM was used and comes from:

<https://www.microchip.com/DM240001-2>

#### 6.1.1 Demo Code and Coverage Colors

For the `case '\n'` statement shown:

- Both `if` statement conditions are executed and so shown as green (covered and executed).
- Both `if` statements have evaluated as false and so the following functions are shown as red (covered but not executed).
- The `else` of the second `if` statement applies and so the following function is executed and shown as green.
- The `break` of the `case` statement is shown as yellow or partially covered (covered but partially executed) which seems unexpected as both `if` statements have executed. To understand what is going on with partial coverage it is useful to view the Program Memory window.



As you can see, viewing Program Memory can help you understanding why a line is partially covered (yellow). In general partially-covered lines can be minimized by writing tests to remove red lines (covered by not executed). Then the remaining yellow lines can be examined in assembly in the Program Memory window.

### 6.1.2 Code Coverage Window

To open the Code Coverage window, select *Windows>Debugging>Code Coverage*. This window shows you how successful your test code was at covering your application code.

When program execution is halted, the current coverage percentages for each file in the application will be shown. Click on the arrow to see a breakdown of coverage for functions in the file.

Coverage is expressed in Address Units, where an Address Unit represent the atomic unit of memory addressable by the execution portion of the project device architecture.

The Coverage percentage (in green) represents  $x/(x+y)$ , where  $x$  = address units covered and  $y$  = address units not covered.

**Figure 6-3. Code Coverage Window**

Code Coverage	Variables	Call Stack	Breakpoints	Output	
File Name	Address Units Covered	Address Units Not Covered	Coverage		
▼ adc.c	184	94	66%		
Ⓜ ADC_Read10bit	86	12	87%		
Ⓜ ADC_ChannelEnable	28	12	70%		
Ⓜ ADC_ReadPercentage	0	66	0%		
Ⓜ ADC_SetConfiguration	70	4	94%		
▶ leds.c	162	558	22%		
▶ main.c	134	0	100%		
▶ lcd.c	522	188	73%		
▶ system.c	10	144	6%		
▶ buttons.c	74	90	45%		
▶ timer_1ms.c	322	84	79%		
▶ lcd_printf.c	22	0	100%		
▶ rtcc.c	922	282	76%		

## 6.2 Simple Code Example

Figure 6-4. Editor Window - Simple Code Example

```

1  /*
2  * File:   main.c
3  */
4
5  #include "xc.h"
6
7  volatile int i, j = 0, n = 5, m;
8  volatile int a = 1, b = 0, c, d = 10, e = 20;
9
10 int main(void) {
11
12     // simple if statement
13     if(a < b ) j = 1;
14
15     // for statement example
16     for (i = 0; i < n; i++) {
17         m = j++;
18         if (m > i){
19             break;
20         }
21     }
22
23     // if-else example
24     if (a || b)
25         c = calcAdd(d,e);
26     else
27         c = calcSub(d,e);
28
29     // while example
30     //while(1);
31
32     return 0;
33 }
34

```

Simple C code constructs are used to demonstrate code coverage.

### 6.2.1 Simple Code and Coverage Colors

#### No Color - No Coverage Data

Several C constructs do not generate executable code, so have no highlight. Examples shown above include:

- Preprocessor declarations - #include statements
- Variable declarations and initializations
- Comments or commented out code

#### Green - Covered and Executed

Full coverage for a line occurs when the code on that line is executed completely.

The main() function executes and returns completely, so the beginning, return and ending lines show full coverage.

The lines of the `for` loop are all executed to completion except for the `break` statement, because the `if` condition is never met. In loops and conditional statements, there are one or more conditions or branches which must all be tested for full coverage.

Functions that are called and complete on a line, such as `calcAdd()`, are fully covered.

### Yellow - Partial Coverage

When code on a line is covered but only partially executed, this is considered partial coverage.

For the simple `if` statement, the evaluation of `a<b` is executed but the assignment `j=1` is not. Therefore the line is partially covered. If the statements were on different lines, you will see:

```
// simple if statement
if(a < b )
    j = 1;
```

The `if-else` statement uses binary logic to determine the branch condition. Because of the variable values chosen, the statement is only partially covered because when `a` has a nonzero value, `b` will not be evaluated.

### Red - Covered but not Executed

As discussed above, in loops and conditional statements there are one or more conditions or branches which must all be tested for full coverage.

The `if` statement in the `for` loop is never true, so the following `break` statement is not executed.

The condition of the `if-else` statement is evaluated so the `else` branch is never selected and the following line with `calcSub()` is not executed.

## 6.2.2 Limitations of Coverage in the Editor

The Editor window displays lines of C code. C is a high-level language where one line of C code can represent one or more device instructions, depending on the device. Therefore, looking at the actual device instructions in the Program (or Execution Memory) window may be necessary to determine the reason(s) for the coverage shown.

An example is the `while(1)` loop commented out in the code. If it is uncommented and the program is run again and then paused, the following text may display in the Output window:

```
No source code lines were found at current PC 0x330. Open program memory view to see
instruction code disassembly.
```

To open the Program Memory (8- or 16-bit devices) window, select Windows>Target Memory Views>Program Memory. To open the Execution Memory (32-bit devices) window, select Windows>Target Memory Views>Execution Memory.

Figure 6-5. Program Memory - Simple Code Example

```

29 // while example
30 while(1);
31
32 return 0;
33 }
34

```

Line	Address	Opcode	Label	DisAssy
400	0031E	070009		RCALL calcAdd
401	00320	884040		MOV W0, c
402	00322	370005		BRA .L9, .L26
403	00324	A8A814		BSET __cc_bits_main_c_4d7c040b, #5
404	00326	804081		MOV 0x810, W1
405	00328	804070		MOV 0x80E, W0
406	0032A	07000B		RCALL calcSub
407	0032C	884040		MOV W0, c
408	0032E	A8E814		BSET __cc_bits_main_c_4d7c040b, #7
409	00330	37FFFE		BRA .L9, .L26
410	00332	FA0004	calcAdd	LNK #0x4
411	00334	A80818		BSET __cc_bits_math_c_4dae163e, #0
412	00336	780F00		MOV W0, [W14]
413	00338	980711		MOV W1, [W14+2]

At address 0x330 is a branch instruction; therefore the compiler has generated this representation of while(1). This will not be seen as source code and so the Output text is generated.

### 6.2.3 Code Coverage by Project File

For the Simple Code Example, the Code Coverage window percentages are not difficult to see given the coverage in the Editor window. For more complex applications (such as the Demo Code), the breakdown of coverage by file and function provides useful information for improving tests and coverage.

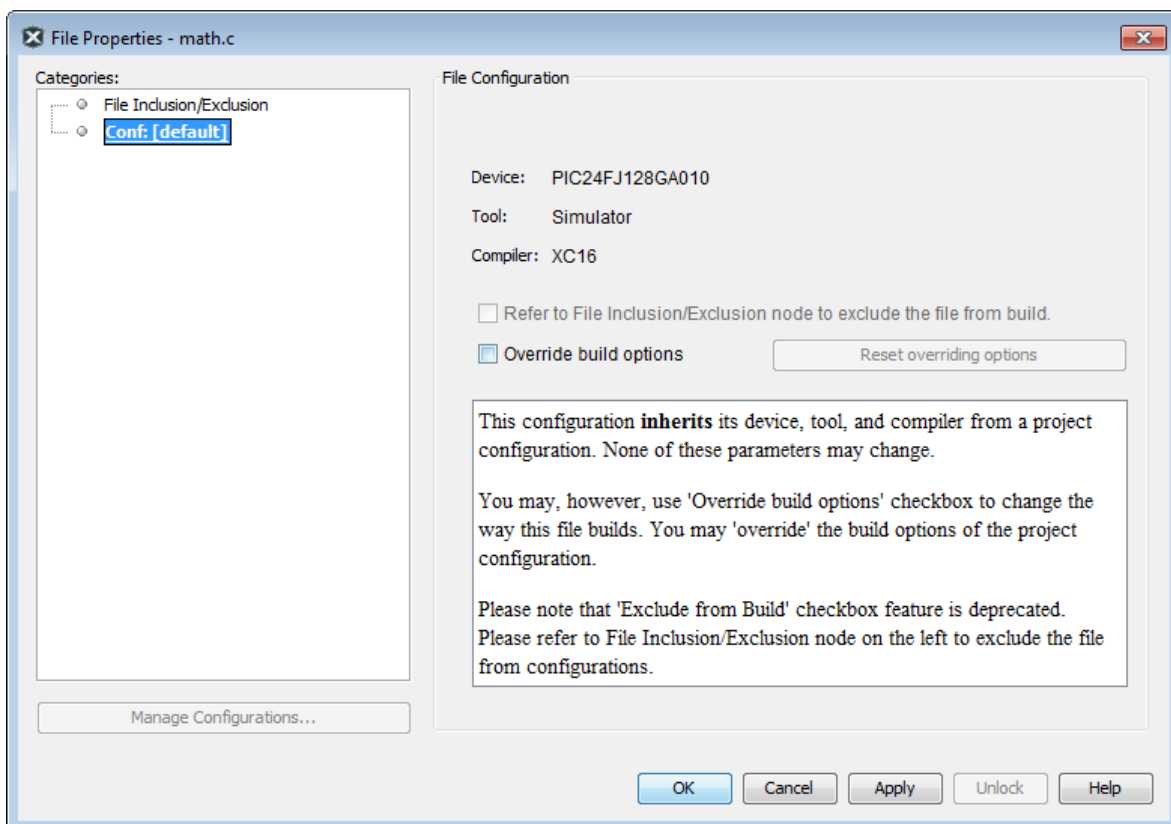
Figure 6-6. Code Coverage Window - Simple Code Example

File Name	Address Units Covered	Address Units Not Covered	Coverage
math.c	16	16	50%
calcAdd	16	0	100%
calcSub	0	16	0%
main.c	72	14	83%
main	72	14	83%

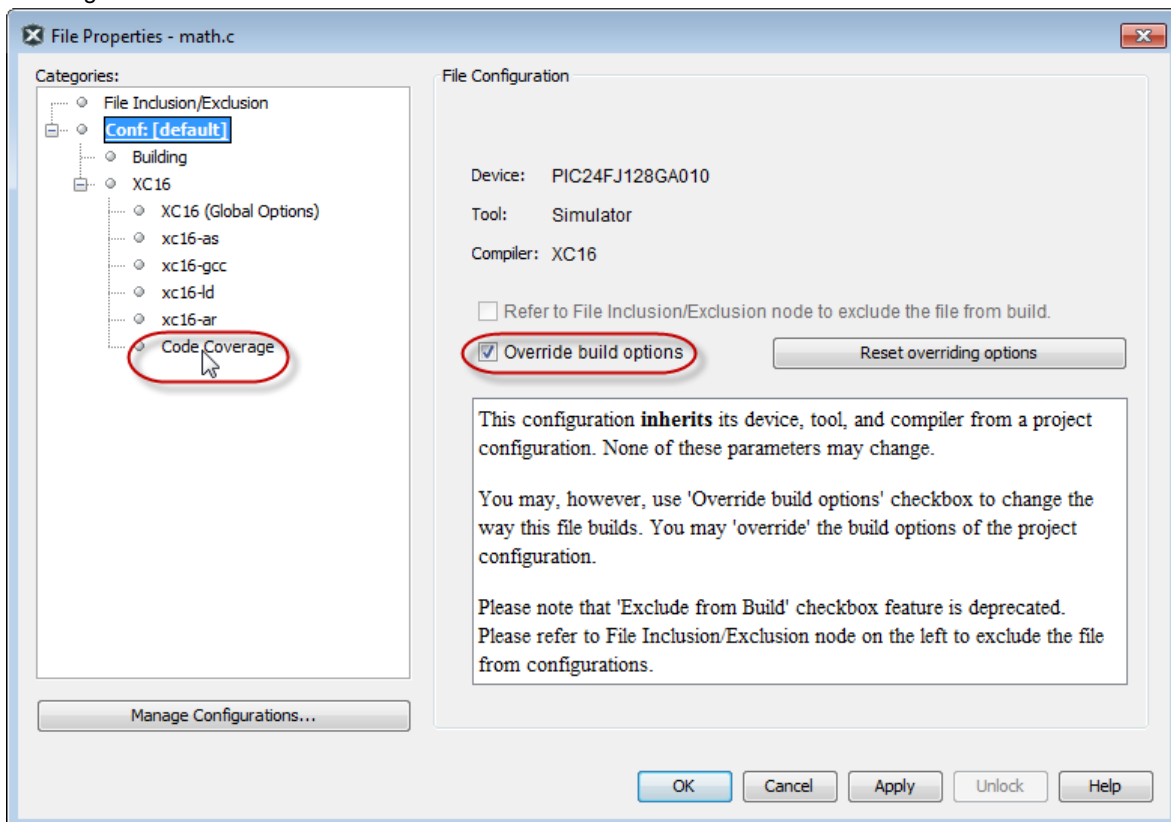
To provide targeted code coverage for specific file(s) in the project, you can change the file build properties.

1. Right click on a project file and select "Properties" from the drop-down menu. The "File Properties" dialog will open.

## Understand Code Coverage Output

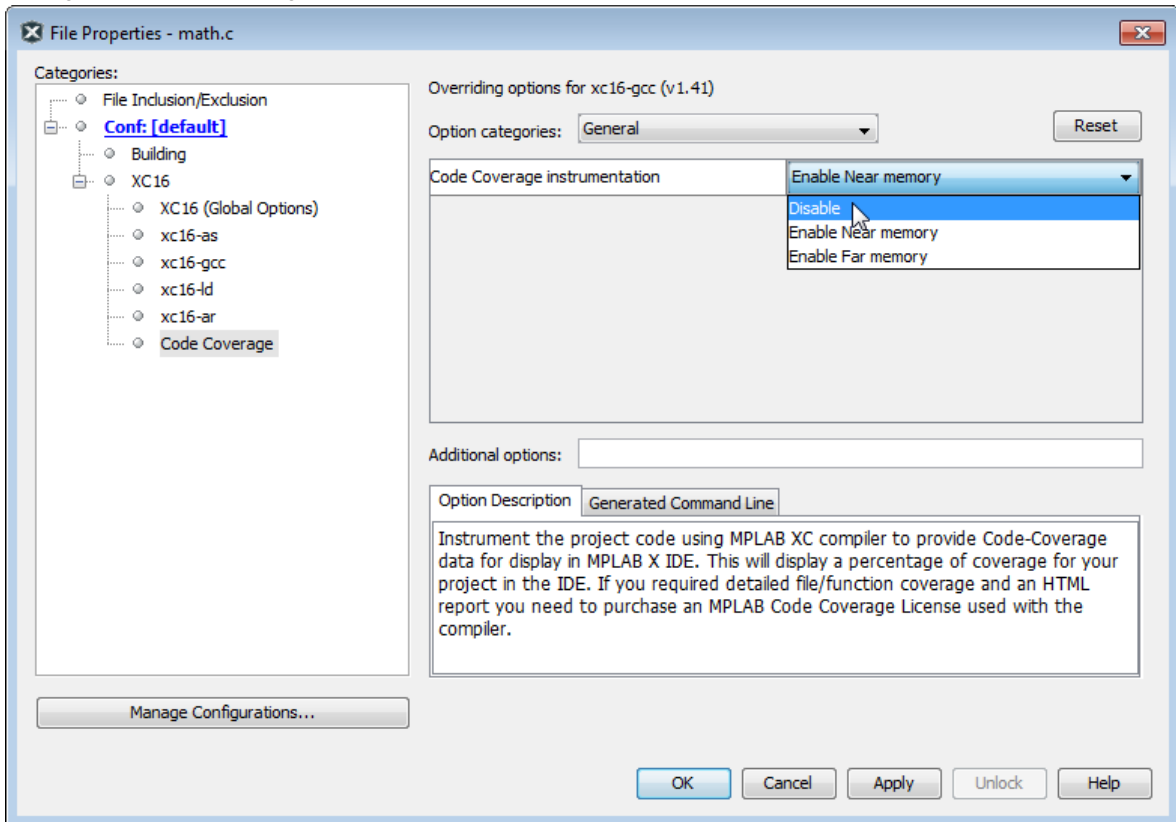


2. In this dialog, check "Override build options." Now other build option selections will appear. Click on "Code Coverage."





3. Change the “Code Coverage instrumentation” option to “Disable” and then click **OK**.



4. The file will now show in the project as bolded. Run and halt the project and examine the Code Coverage window. The file will no longer be listed here. Open the file in the Editor to see that no code coverage highlighting is available.

# Understand Code Coverage Output

The screenshot displays the MPLAB X IDE v5.30 interface for a project named SimpleXC16Example. The main window shows the source code for math.c, which includes two functions: calcAdd and calcSub. The code coverage table at the bottom indicates that 83% of the code in main.c is covered.

```
1  /*
2  * File:   math.c
3  */
4
5  /*
6  * Prototypes
7  */
8  int calcAdd(int a,int b);
9  int calcSub(int a,int b);
10
11 /*
12 * Functions
13 */
14 int calcAdd(int a,int b){
15     return a+b;
16 }
17
18 int calcSub(int a,int b){
19     return a-b;
20 }
```

File Name	Address Units Covered	Address Units Not Covered	Coverage
main.c	72	14	83%

## 7. Create a Code Coverage HTML Report

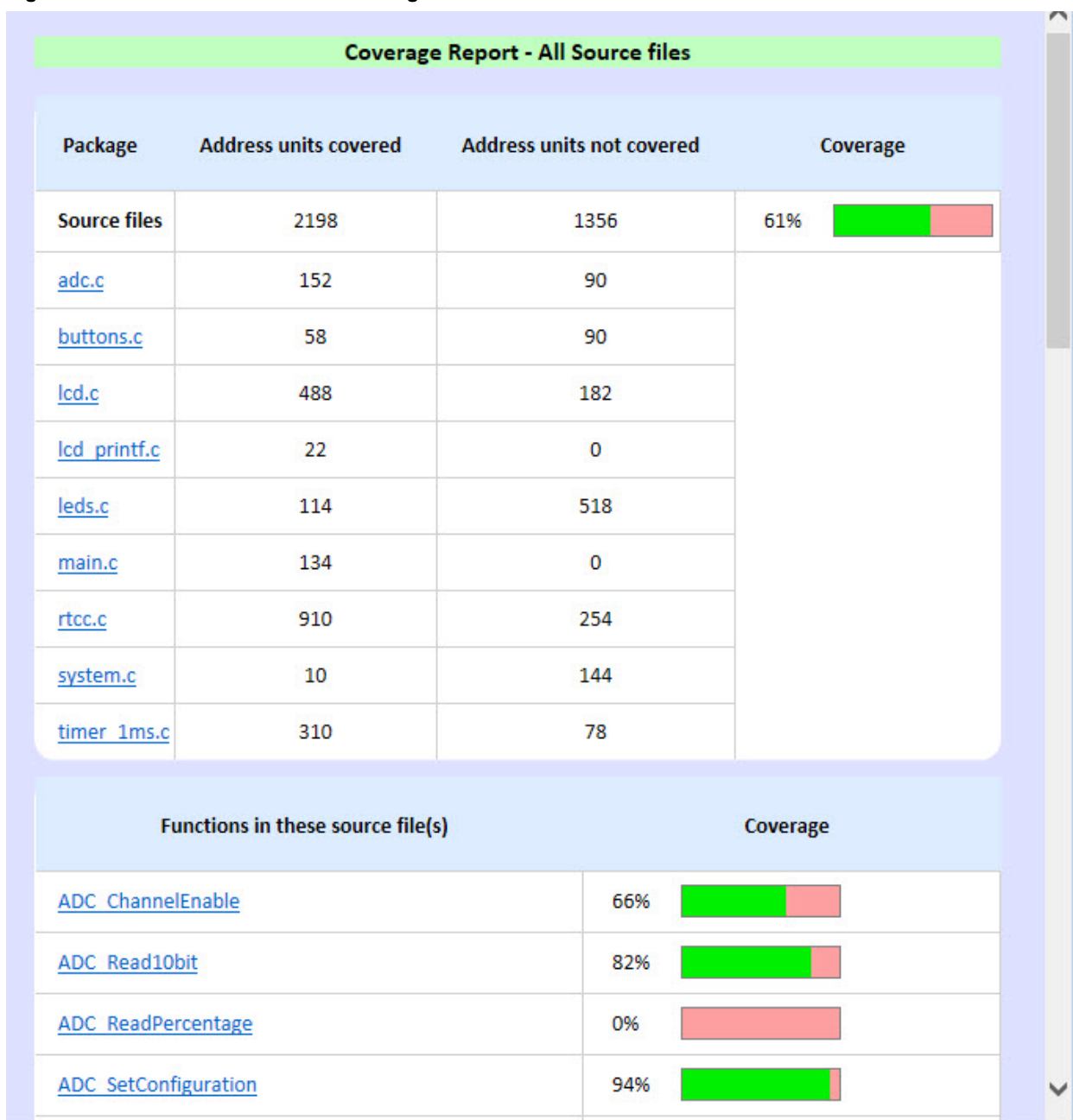
Code coverage information may be saved into a file by clicking on the **Generate HTML Report** button  on the **Code Coverage** tab.

For information on the meaning of Coverage colors, see section [5.1 Highlight Colors](#).

**Figure 7-1. Source Files List and Coverage**

Source files
<a href="#">All</a>
<a href="#">adc.c</a>
<a href="#">leds.c</a>
<a href="#">main.c</a>
<a href="#">lcd.c</a>
<a href="#">system.c</a>
<a href="#">buttons.c</a>
<a href="#">timer_1ms.c</a>
<a href="#">lcd_printf.c</a>
<a href="#">rtcc.c</a>
All Source files
<a href="#">adc.c</a> (62%)
<a href="#">leds.c</a> (18%)
<a href="#">main.c</a> (100%)
<a href="#">lcd.c</a> (72%)
<a href="#">system.c</a> (6%)
<a href="#">buttons.c</a> (39%)
<a href="#">timer_1ms.c</a> (79%)
<a href="#">lcd_printf.c</a> (100%)
<a href="#">rtcc.c</a> (78%)

Figure 7-2. Source Files List and Coverage Details



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- Embedded Solutions Engineer (ESE)
- Technical Support

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Technical support is available through the website at: <http://www.microchip.com/support>

## Microchip Devices Code Protection Feature

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Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

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## Quality Management System

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