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Empowering Embedded Systems

μC/OS-II
μC/LCD
μC/Probe

and

The Freescale MC9S12DG256

(Using the Wytec Dragon12-Plus Evaluation Board)

Application Note

AN-1456

www.Micrium.com

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1.00 Introduction

This document shows example code for using **μC/OS-II**, **μC/LCD** and **μC/Probe** on a Freescale MC9S12DG256 processor. To demonstrate the MC9S12DG256, we used a Wytec Dragon12-Plus Evaluation Board as shown in Figure 1-1.

We used the Freescale Codewarrior IDE version 4.5 and Freescale Serial Monitor to compile and load this application. However, other tool-chains may be used.

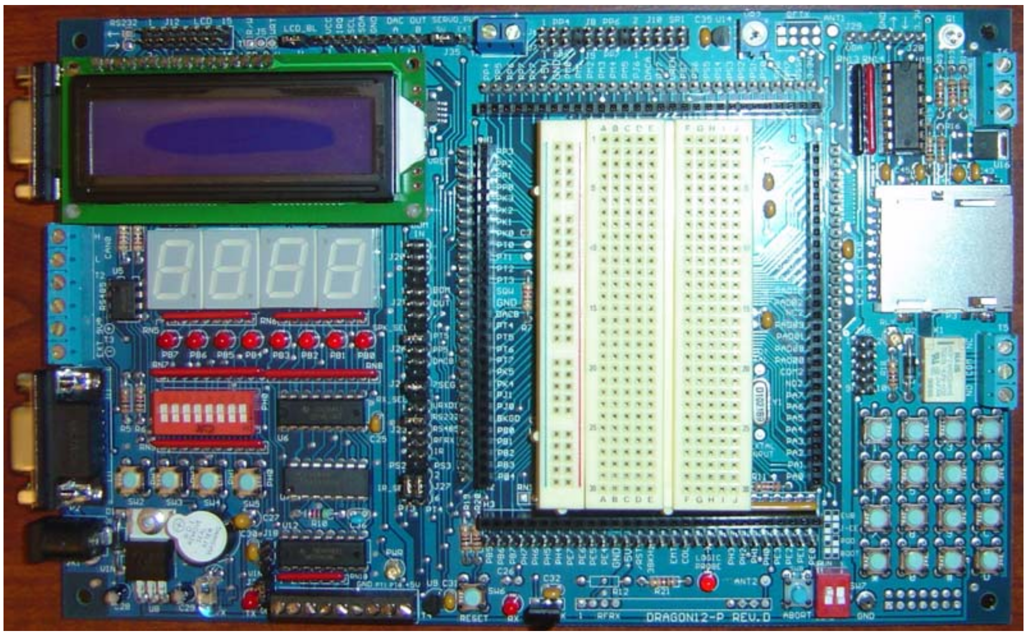


Figure 1-1, Wytec Dragon12-Plus Evaluation Board

The application code is downloaded into flash memory using the Freescale serial monitor application. The serial monitor has been preinstalled within the MC9S12 flash memory prior to shipping from Wytec. In order to download the demonstration application to the MC9S12, the host PC must have an available serial port. If a serial port is unavailable, it is possible to download and debug the application using a P&E Multilink BDM and changing the project configuration settings found above the build tree from ‘HCS12 Serial Monitor’ to ‘P&E Multilink Cyclone Pro’.

Once the application has been loaded into the MCU flash memory, the user may either run the application from the debugger or switch the EVB to RUN mode and press reset. Once the application is running, the onboard LCD and seven segment displays will update. After a few seconds, the user will be prompted via the LCD that the keypad is available for use. Keys pressed during this time will be displayed on the bottom row of the LCD.

1.01 Source code access

This application note describes a demonstration application using **μC/OS-II**, **μC/LCD**, and **μC/Probe** and is based on **μC/OS-II** Version 2.86.

Micrium's policy in regards to getting access to source code is as follows:

> **μC/OS** and **μC/OS-II** source and object code can be used by accredited Colleges and Universities without requiring a license, as long as there is no commercial application involved. In other words, no licensing is required if **μC/OS** and **μC/OS-II** is used for educational use.
>
> You need to obtain an 'Object Code Distribution License' to embed **μC/OS** or **μC/OS-II** in a product that is sold with the intent to make a profit or if the product is not used for education or 'peaceful' research.
>
> You also need to obtain a 'Source Code Distribution License' to distribute **μC/OS** or **μC/OS-II** in source code form.

For all the **μC/** products other than **μC/OS-II**, you need to obtain an 'Object Code Distribution License' to get access to the source code.

1.02 Quick Start Guide

Prerequisites:

1. Codewarrior 4.5 or better. A valid license file must be present. The standard demonstration Codewarrior license is limited to 32 files and will not be sufficient for compiling the provided application. If you do not have a full featured license and belong to an academic institution, one may be obtained by contacting Freescale support.

2. Dragon12-Plus EVB.

3. Available serial port on the host computer. A standard UART is required by Codewarrior when using the 'serial monitor' configuration to connect to MC9S12 MCU. The cable should be connected between the host PC and SCI0 on the Dragon12-Plus.

Instructions:

1. Unzip AN1456 to c:\. This will result in the c:\Micrium\ directory being created. It is recommended that you unzip to the default directory since it adheres to AN2002, 'Directory Structure' and makes supporting applications easier. It also provides for a consistent directory structure with regards to version controlling several projects that share the same base code.

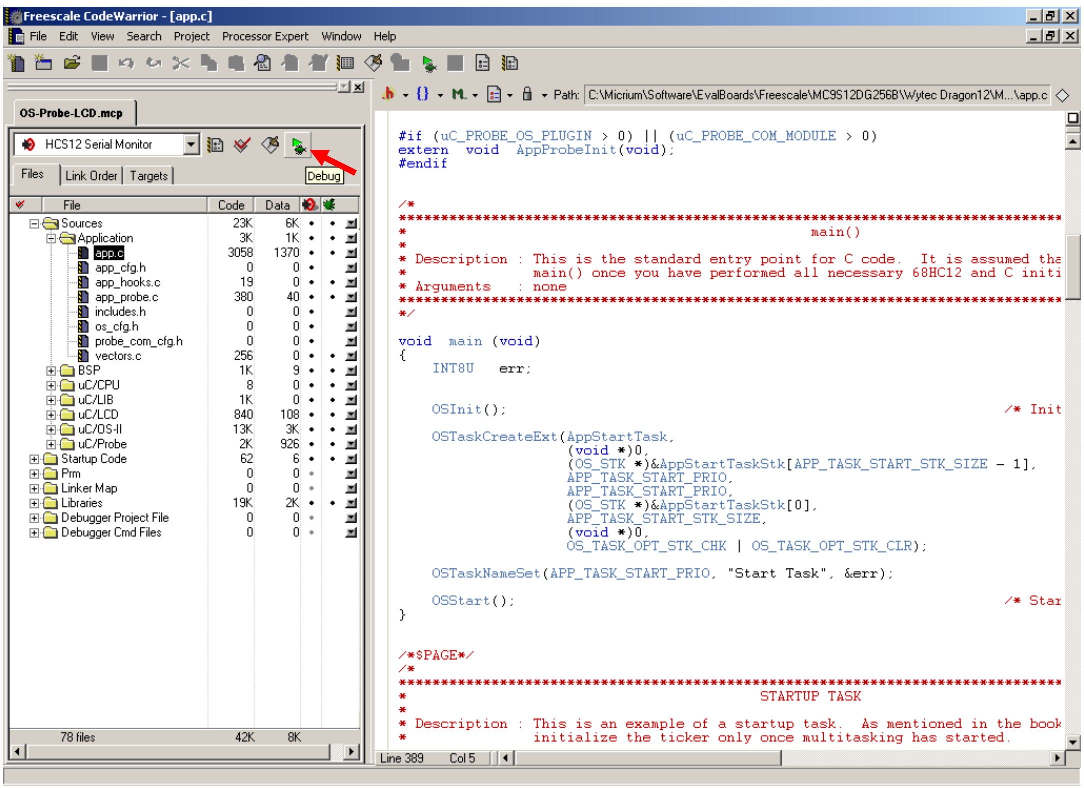
2. Open the project file using Codewarrior version 4.5 or better. The project file is located in the following directory and is named *OS-Probe-LCD.mcp*.

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec\Dragon12\Metrowerks\Page \OS-Probe-LCD

3. Ensure that the Dragon12-Plus 'Run/Load' switch is in the 'LOAD' position. This may be accomplished by switching the left hand switch of SW7 to the 'down' position.

4. Ensure that the current build configuration is set for 'HCS12 Serial Monitor'. This can be verified by viewing the pull-down box above the source code tree illustrated in the screen shot below.

5. Build and load the application by clicking on the green debug button illustrated by the red arrow.



6. Once the application has been loaded, there are two options.
   a. Press the green arrow within the debugger to launch the application in debug mode.

   b. Change the left SW7 to the up position, 'RUN' mode, close the debugger and reset the target. This will cause the application to run in stand-alone mode.

7. Additionally, you may visit the Micrium web site, www.micrium.com, and download the latest trial version of **μC/Probe**. **μC/Probe** allows global variables to be graphically mapped via a Windows application to various counters, gauges, spreadsheets, switches and knobs for both viewing and changing during run-time. If **μC/Probe** is utilized, a second serial cable will need to be attached between the PC and SCI1 of the Dragon12-Plus EVB. See the section labeled **μC/Probe** for more information.

8. Once the application is running, the LCD and seven segment displays should update. After a short while, the application will prompt the user via the LCD screen indicating that keypad entry is now possible.

1.03 Hardware Configuration

1. Enable seven segment LED blocks by placing J24A and removing J24B.
2. Enable SCI1 for RS232 communication by setting J23 to position 2, the SCI1 setting.
3. Set the left switch of SW7 to the down position to enable LOAD mode. Once the application is running and debugging is no longer necessary, the user may move the left SW7 switch to the up position to enable RUN mode. From this mode, the MCU / serial monitor will automatically start the user application upon power up.

Pins in use:

1. Port A, on-board keypad.
2. Port B, seven segment LED blocks.
3. Port K, character LCD.
4. PS0 through PS3. SCI0 for the serial monitor and SCI1 for **µC/Probe**.

1.04 Port Specific Details

This **µC/OS-II** processor port has been designed to operate in the MC9S12 banked memory model. Paging must not be enabled within the Codewarrior project options since the PPAGE register save and restore functionality has been included in the **µC/OS-II** port.

Additionally, this **µC/OS-II** port has been customized to work in conjunction with the Freescale serial monitor application. As a result, this port will NOT work when the MCU is in expanded mode since the ability to use SWI to perform context switches has been replaced with the JSR, opposed to the CALL instruction. Applications that are loaded and run without the serial monitor are encouraged to use the non serial monitor compliant port as it offers slightly improved context switch performance via SWI.

This application assumes the presence of an 8MHz crystal on the Dragon12-Plus EVB. Once the application has been initialized, the on-chip PLL is configured to 48MHz which results in a 24MHz. bus clock. The PLL settings may be changed from within *bsp.h*. Refer to the section labeled "Configuring the PLL" for more information.

Next, **µC/OS-II** requires the use of an ECT channel for periodic time keeping. This application configures ECT channel 7 for the **µC/OS-II** Ticker, however, if TC7 is not available, you may configure an alternate ECT timer channel by adjusting the macro named "`OS_TICK_OC`" within *bsp.h* accordingly. If the ECT channel is changed, then the file *vectors.c* will also require modification. See the section labeled "vectors.c" for more information.

Lastly, all ISRs must be written as specified within the section labeled "Creating Interrupt Service Routines". Creating ISRs from 'C' without the proper **µC/OS-II** primitives will cause task scheduling jitter which could result in poor real-time performance for some applications.

1.05 μC/Probe

μC/Probe is a Microsoft Windows program that displays the content of system variables on various user definable graphical elements such as simulated mechanical counters, graphs, on-screen LEDs and so on.

In order for **μC/Probe** to display information about your application, an ELF file, must be generated by the user's compiler. The ELF file contains the names and addresses of all the global symbols referenced within the users embedded application. Only symbols that have been allocated memory, e.g. not allocated on the stack, are able to be monitored by **μC/Probe**. Global and static variables are examples of variables that may be monitored.

The user places components (such as gauges, labels, and charts) into a Data Screen in a **μC/Probe** workspace. Each one of these controls is then assigned to one or more of the variables from the Symbol Browser. The Symbol Browser lists all symbols referenced from within the ELF file. Symbols associated with components placed on an open Data Screen will be updated after the user presses the start button (assuming the user's PC is connected to the target and the target is running).

μC/Probe currently interfaces with a target processor via JTAG, RS-232, UDP and USB. A small section of code resident on the target receives commands from the Windows application and responds to those commands. The commands ask for a certain number of bytes located at a certain address, for example, "Send 16 bytes beginning at 0x0040102C". The Windows application, upon receiving the response, updates the appropriate component(s) on the data screen(s) with the new values.

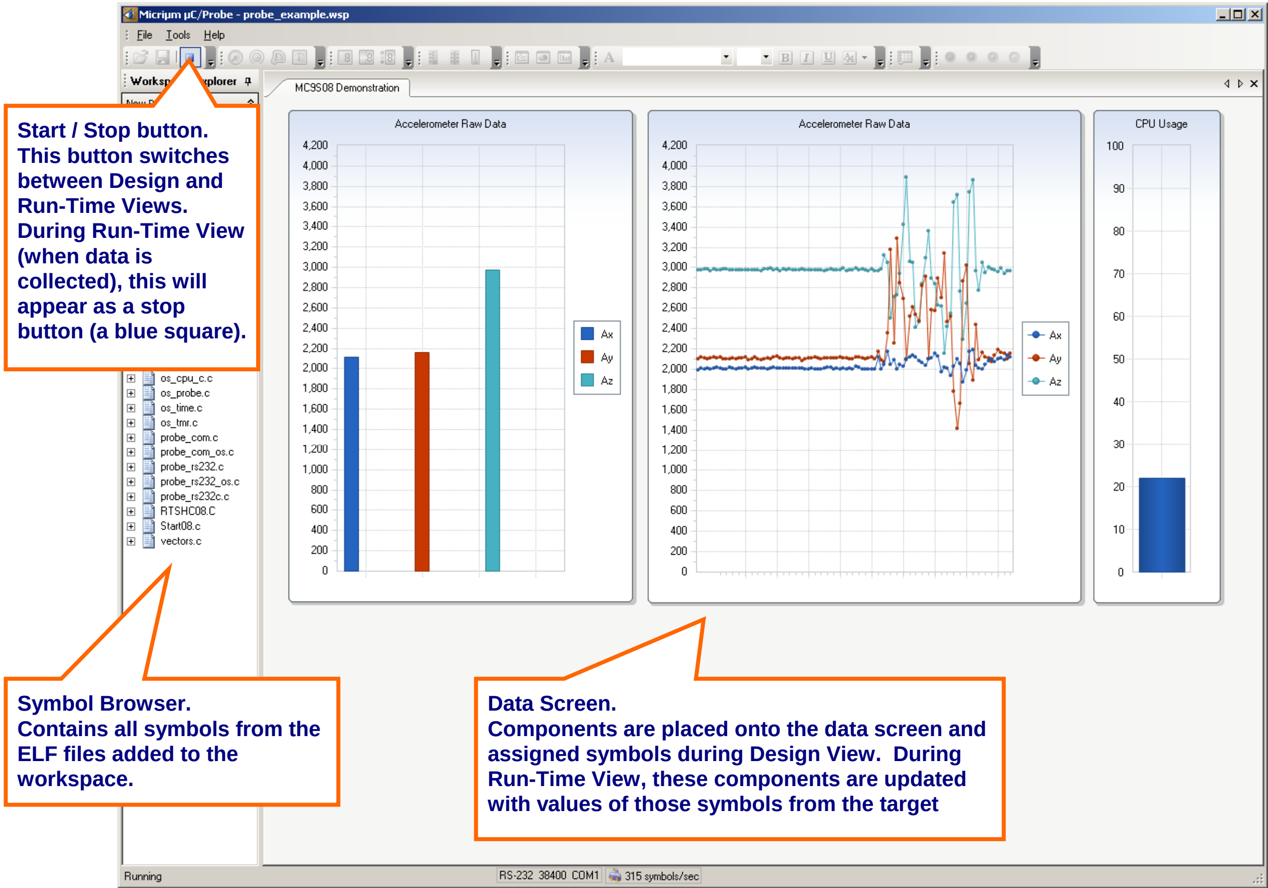


Figure 2-1. μC/Probe Windows Program

To use **μC/Probe** with the example project (or your application), do the following:

1. **Download and Install μC/Probe.** A trial version of **μC/Probe** can be downloaded from the Micriμm website at

   http://www.micrium.com/products/probe/probe.html

2. **Open μC/Probe**. After downloading and installing this program, open the example **μC/Probe** workspace for **μC/OS-II**, named ***OS-Probe.wsp***, which should be located in the AN-1456 Codewarrior project directory.

   You may also open one of the sample workspaces that come with **μC/Probe**. The sample workspace files are located in the **μC/Probe** target directory.

3. **Connect Target to PC**. Currently, **μC/Probe** can use RS-232 to retrieve information from the target. You should connect a RS-232 cable between your target and computer.

   Load Your ELF File. The example projects included with this application note are already configured to output an ELF file. (If you are using your own project, please refer to Appendix A of the **μC/Probe** user manual for directions for generating an ELF file with your compiler.) Codewarrior generates an ELF file with an .abs extension. This file is located in a directory named BIN within the sample project directory.

To load this ELF file, right-click on the symbol browser and choose “Add Symbols”. Navigate to the file directory, select the file, and choose “OK”.

4. **Configure the RS-232 Options**. In **μC/Probe**, choose the “Options” menu item on the “Tools” menu. A dialog box as shown in Figure 6-2 (left) should appear. Choose the “RS-232” radio button. Next, select the “RS-232” item in the options tree, and choose the appropriate COM port and baud rate. The baud rate for the project accompanying this application note is 115,200.

5. **Start Running**. You should now be ready to run **μC/Probe**. Just press the run button to see the variables in the open data screens update.

1.06 Directories and Files

The code and documentation of the port are placed in a directory structure according to “AN-2002, μC/OS-II Directory Structure”. Files for the banked serial monitor and non serial monitor compliant ports have been supplied by Micrium. Specifically, the files are placed in the following directories:

μC/OS-II:

\Micrium\Software\uCOS-II\Source

This directory contains the processor independent code for **μC/OS-II**. The version used was 2.86.

\Micrium\Software\uCOS-II\Ports\HCS12\Paged\Metrowerks
\Micrium\Software\uCOS-II\Ports\HCS12\Paged\Metrowerks\SerialMonitor

These directories contain the standard processor specific files for a **μC/OS-II** port assuming the Freescale Codewarrior IDE. These files could easily be modified to work with other tool chains; however, you would place the modified files in a different directory.

Only one processor port, non serial monitor compliant or serial monitor compliant may be compiled in to a **μC/OS-II** project at any given time. When switching ports, it is necessary to remove the old port files from the build tree, add the new port files, and adjust the access path settings to ensure that Codewarrior does not observe header files from the old port directory.

Specifically, the required files are:

os_cpu.h
os_cpu_a.s
os_cpu_c.c

μC/Probe:

C:\Micrium\Software\uC-Probe\Target\Communication\Generic\OS\uCOS-II

This directory contains the OS dependent interface for the communication layer of **μC/Probe**. If you plan to run **μC/Probe** with a different RTOS, or without any RTOS, the following files would have to be adjusted accordingly:

probe_com_os.c

C:\Micrium\Software\uC-Probe\Target\Communication\Generic\RS-232\OS\uCOS-II

This directory contains OS dependent interface code for the RS-232 specific portion of **μC/Probe**, specifically the code necessary to generate an optional Rx packet parse task. If you plan to run **μC/Probe** with a different RTOS, modifications to the files listed below will have to be made. If you are not running an RTOS, the following files may be excluded from the build.

probe_rs232_os.c

C:\Micrium\Software\uC-Probe\Target\Communication\Generic\RS-232\Ports\Freescale\MC9S12

This directory contains the **μC/Probe** hardware port files for the MC9S12 processor.

probe_rs232c.c
probe_rs232c.h
probe_rs232_ba.s

C:\Micrium\Software\uC-Probe\Target\Communication\Generic\RS-232\Source

This directory contains target independent source code for the **μC/Probe** RS-232 communication layer. Specifically, this directory contains the following files:

probe_rs232.c
probe_rs232.h

C:\Micrium\Software\uC-Probe\Target\Communication\Generic\Source

This directory contains target independent source code for the **μC/Probe** communication layer. Specifically, this directory contains the following files:

probe_com.c
probe_com.h

C:\Micrium\Software\uC-Probe\Target\Plugins\uCOS-II

This directory contains the target independent source code for **μC/Probe**. Specifically, this directory contains the following files:

os_probe.c
os_probe.h

Application Code:

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec\Dragon12\Metrowerks\Paged \OS-Probe-LCD

This directory contains the Freescale Codewarrior project file for the AN-1456.

OS-Probe-LCD.mcp

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec\Dragon12\Metrowerks\Paged \OS-Probe-LCD\Source

This directory contains the source code for an example running on the Dragon12-Plus evaluation board. It assumes the presence of **μC/OS-II**.

This directory contains:

app.c
app_cfg.h
app_hooks.c
app_probe.c
datapage.c
includes.h
os_cfg.h
probe_com_cfg.h
Start12.c
vectors.c

app.c contains the application entry point, `main()` and example code.

app_cfg.h contains application specific configuration information such as task priorities and stack sizes. It is highly recommended that users continue to use the *app_cfg.h* for all application configuration constants instead of placing defines within several different files.

A*pp_hooks.c* contains application software hooks for many OS functions such as context switching and idle task iterations. **μC/Probe** makes use of the **μC/OS-II** hooks in order to use idle processor time for making various measurements.

App_probe.c contains initialization code for **μC/Probe**.

Includes.h is a master include file used by the application. It is recommended, but not necessary that users include additional files from *includes.h*.

os_cfg.h is the **μC/OS-II** configuration file. Unused features of the operating system may be disabled from within this file in order to reduce the ROM and RAM footprint of the OS. By default, all features are enabled and the OS ticker is configured to run 1000 times per second. This equates to a timer resolution of 1 millisecond.

Probe_com_cfg.h is a configuration file for **μC/Probe**. By default, **μC/Probe** has been configured for task priority 9, a stack size of 160 bytes, a receive buffer of 64 bytes, and configured to use SCI1. Any of these configuration values, including SCI selection, may be changed if necessary.

`Datapage.c` and `start12.c` are provided by Codewarrior but have been placed in the application directory for code warrior project consistency purposes.

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec ragon12\Metrowerks\Paged\BSP

This directory contains the Board Support Package for the Dragon12-Plus evaluation board. Some of the code in this directory may work on other MC9S12 derivatives, however, routines that are hardware dependent such as `LED_On()` will require modification depending on the hardware design of the EVB.

Please see the section labeled "Board Support Package" and "Porting to Other MC9S12 Derivatives" for more information related to the BSP.

This directory contains:

bsp.c
bsp.h
keypad.c
keypad.h
sevenSegDisp.c
sevenSegDisp_OS.c
sevenSegment.s
sevenSegDisp.h
nvm.c
nvm.h
Vectors.c

bsp.c contains hardware specific source code for LED services, PLL initialization, **μC/OS-II** ticker initialization, **μC/LCD** hardware access routines, **μC/Probe** timer routines, and general purpose functions for obtaining clock frequencies during run-time. It is highly recommended that utilize the BSP functionality and not hardcode clock dividers during build time.

bsp.h contains macros for configuring the system PLL and **μC/OS-II** time tick ECT channel. Please see the section labeled "Porting to Other MC9S12 Derivatives" for more information related to the *bsp.h*.

nvm.c and *nvm.h* contain hardware access functions for reading and writing both Flash and EEPROM during run-time. Neither of these files are used within the example but have been provided for convenience. Special care should be taken when modifying the contents of Flash or EEPROM during run-time as it may be possible to overwrite portions of the application accidentally.

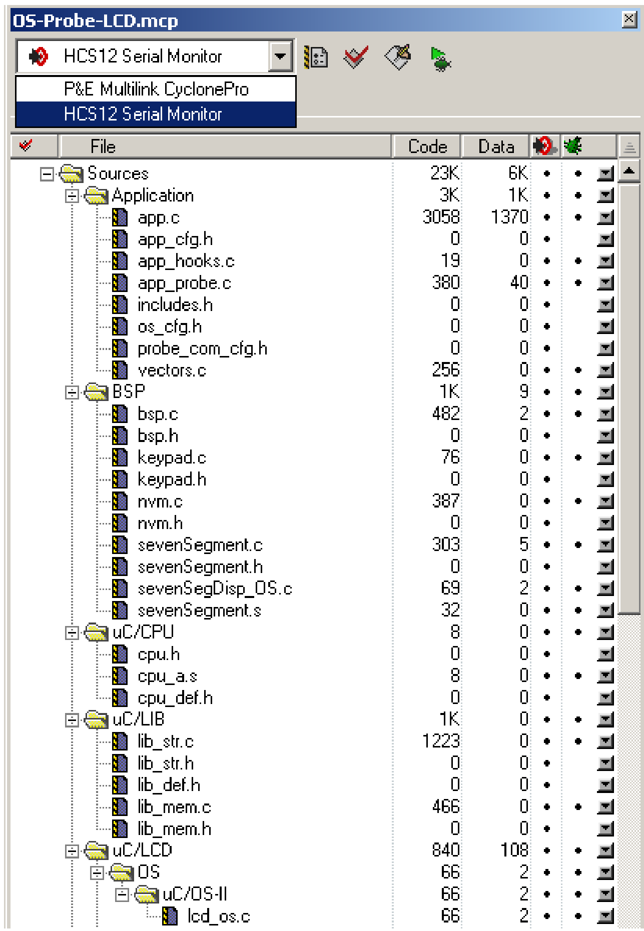
vectors.c contains the processor interrupt vector table. This array of Interrupt Service Routine addresses must be updated whenever a new interrupt is being configured on the system. Interrupt vectors that are not in use should be plugged with the appropriate Dummy ISR handler provided. The serial monitor automatically copies user specified vectors into the serial monitor secondary vector table.

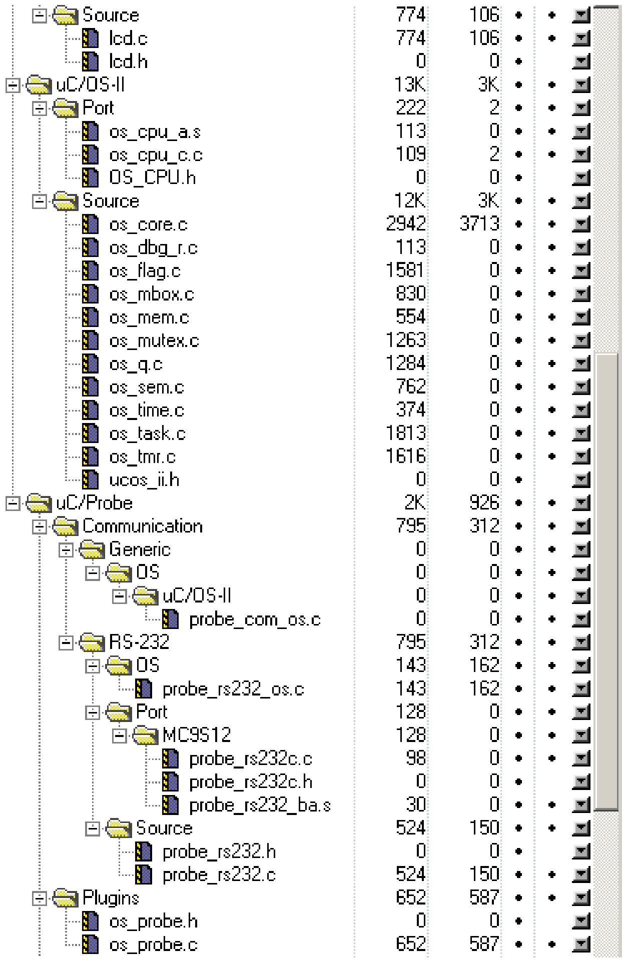
\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec Dragon12\Metrowerks\Paged\OS-Probe-LCD\prm

This directory contains the processor linker files. When a new Codewarrior project is created, the startup vector is automatically placed in the active project's linker file. The user MUST remove all vectors from the .prm files and use the provided *vectors.c* instead. Failure to remove the startup vector from the linker file will result in a linker error during link time. The linker file is derivative dependent. If a different MC9S12 MCU is to be used, please see the section labeled “Porting to Other MC9S12 Derivatives below”

1.07 Codewarrior IDE

We used the Freescale Codewarrior IDE version 4.5 to compile and run the MC9S12DG256 example. You can of course use **μC/OS-II** with other tools. Figures 1-3 shows the project source tree with all of the files necessary to build the example.




Source 774 106
lcd.c 774 106
lcd.h 0 0
uC/OS-II 13K 3K
Port 222 2
os_cpu_a.s 113 0
os_cpu_c.c 109 2
OS_CPU.h 0 0
Source 12K 3K
os_core.c 2942 3713
os_dbg_r.c 113 0
os_flag.c 1581 0
os_mbox.c 830 0
os_mem.c 554 0
os_mutex.c 1263 0
os_q.c 1284 0
os_sem.c 762 0
os_time.c 374 0
os_task.c 1813 0
os_tmr.c 1616 0
ucos_ii.h 0 0
uC/Probe 2K 926
Communication 795 312
Generic 0 0
OS 0 0
uC/OS-II 0 0
probe_com_os.c 0 0
RS-232 795 312
OS 143 162
probe_rs232_os.c 143 162
Port 128 0
MC9S12 128 0
probe_rs232c.c 98 0
probe_rs232c.h 0 0
probe_rs232_ba.s 30 0
Source 524 150
probe_rs232.h 0 0
probe_rs232.c 524 150
Plugins 652 587
os_probe.h 0 0
os_probe.c 652 587

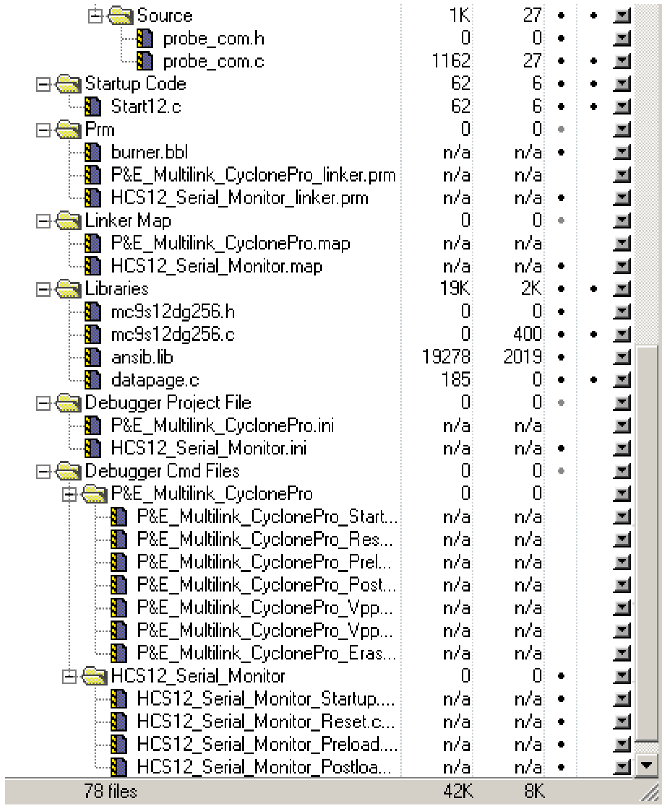


Figure 1-3, Complete Codewarrior Source Tree

2.00 Example Code

As mentioned in the previous section, the example code for this board is found in the following directories and will be briefly described:

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec\Dragon12\Metrowerks\Paged \OS-Probe-LCD

It should be noted that processor header files and libraries are not included within the AN-1456 code archive since they are supplied by Freescale via the Codewarrior installation.

2.01 Example Code, app.c

app.c demonstrates some of the capabilities of **μC/OS-II.**

Listing 2-1, main()

```
void  main (void)                                                  (1)
{
    INT8U  err;


    BSP_IntDisAll();                                               (2)

    OSInit();                                                      (3)

    OSTaskCreateExt(AppStartTask,                                  (4)
                    (void *)0,
                    (OS_STK *)& AppStartTaskStk[APP_START_TASK_STK_SIZE - 1],
                    APP_START_TASK_PRIO,
                    APP_START_TASK_PRIO,
                    (OS_STK *)&AppStartTaskStk[0],
                    APP_START_TASK_STK_SIZE,
                    (void *)0,
                    OS_TASK_OPT_STK_CHK | OS_TASK_OPT_STK_CLR);

#if OS_TASK_NAME_SIZE > 11
    OSTaskNameSet(APP_START_TASK_PRIO, "Start Task", &err);        (5)
#endif

    OSStart();                                                     (6)
}
```

L2-1(1) As with most C applications, the code starts in `main()`.

L2-1(2) We start off by calling a BSP function (see *bsp.c*) that will disable all interrupts. We do this to ensure that initialization doesn't get interrupted in case we do a 'warm restart'.

L2-1(3) As will all **μC/OS-II** applications, you need to call `OSInit()` before creating any task or other kernel objects.

L2-1(4) We then create at least one task (in this case we used `OSTaskCreateExt()` to specify additional information about your task to **μC/OS-II**). It turns out that **μC/OS-II** creates one and possibly three tasks in `OSInit()`. As a minimum, **μC/OS-II** creates a the idle task, `OS_TaskIdle()`. Optionally, the statistics task, `OS_TaskStat()`, and the timer task, `OS_TmrTask()` are created if `OS_STAT_EN` and `OS_TMR_EN` are set to 1 within *os_cfg.h*. Both `OS_TaskStat()` and `OS_TmrTask()` are internal to **μC/OS-II**.

L2-1(5) As of V2.6x, you can now name **μC/OS-II** tasks (and other kernel objects) and be able to display task names at run-time or, with a debugger. In this case, we name our first task 'Start Task'.

L2-1(6) We finally start **μC/OS-II** by calling `OSStart()`. **μC/OS-II** will then start executing `AppStartTask()` since that's the highest priority task created. `OSStart()` does not return.

Listing 2-2, AppStartTask()

```
static  void  AppStartTask (void *p_arg)
{
    (void)p_arg;                                                   (1)

    BSP_Init();                                                    (2)

#if OS_TASK_STAT_EN > 0
    OSStatInit();                                                  (3)
#endif


#if (uC_PROBE_OS_PLUGIN > 0) || (uC_PROBE_COM_MODULE > 0)         (4)
    AppProbeInit();
#endif

    AppTaskCreate();                                               (5)

    while (TRUE) {                                                 (6)
        OSTimeDlyHMSM(0, 0, 0, 500);                               (7)
    }
}
```

L2-2(1) `(void)p_arg` prevents a common compiler warning which says that `p_arg` is not referenced anywhere in the code.

L2-2(2) `BSP_Init()` is called to initialize the Board Support Package – the I/Os, the tick interrupt, and so on. `BSP_Init()` will be discussed in the next section.

L2-2(3) `OSStatInit()`initializes the statistics task which is responsible for counting context switches and so fourth. `OS_TASK_STAT_EN` in `os_cfg.h` is set to `1`.

L2-2(4) This function is called in order to `initialize` **μC/Probe**. The UART baud rate is configured from within *app_probe.c* as 115,200 baud by default. This call may be removed along with the **μC/Probe** files if **μC/Probe** functionality is not required.

L2-2(5) Create additional application tasks through the use of a user supplied function named `AppTaskCreate()`. From here, tasks for updating the LCD, seven segment display, and reading the keypad are created.

L2-2(7) As with ALL task managed by **µC/OS-II**, the task must either enter an infinite loop 'waiting' for some event to occur or terminate itself.

L2-2(8) Delay the task for 500 milliseconds and repeat the contents of the while loop indefinitely. Even though `AppStartTask()` serves as the system startup task, it may be used as a general purpose task. In this particular case, the task body has been left empty and thus may be utilized by the user's application if desired. Otherwise, the task could delete itself and a new task could be created that utilizes the startup tasks stack space.

Listing 2-3, LCD_TestTask()

```
static  void  LCD_TestTask (void *p_arg)
{
       CPU_INT08S  i;
       CPU_INT08U  err;

const  CPU_INT08U  KeypadEnStr[18]    = {"Keypad Enabled"};                       (1)
const  CPU_INT08U  KeypadDisStr[18]   = {"Keypad Disabled"};

const  CPU_INT08U  WelcomeStr[6][18]  = {"Welcome to the", "Dragon 12 EVB.  ",
                                          "This demo runs", "Micrium uC/OS-II",
                                          "on a 48 MHz   ", "MC9S12DG256B CPU"};

const  CPU_INT08U  aboutStr[]         = {"Did you know that uC/OS-II can "
                                          "provide multi-tasking and "
                                          "real-time services to your "
                                          "embedded applications? In fact, "
                                          "uC/OS-II provides services "
                                          "such as task delays, "
                                          "semaphores, message mailboxes, "
                                          "timers, event flags, memory "
                                          "management, mutexes, queues, "
                                          "and much more! "
                                          };

       CPU_INT08U  *aboutStrPtr;


   (void)p_arg;

    DispInit(2, 16);                                                              (2)

    while (DEF_TRUE) {
        DispClrScr();                                                             (3)

        for (i = 0; i < 6; i+=2) {                                                (4)
            DispStr(0, 0, WelcomeStr[i]);
            DispStr(1, 0, WelcomeStr[i+1]);
            OSTimeDlyHMSM(0, 0, 2, 0);
        }

        DispClrLine(1);                                                           (5)

        OSFlagPost(keypadEnFlagGrp, 0x01, OS_FLAG_SET, &err);                     (6)

        while (err != OS_NO_ERR) {                                                (7)
            OSTimeDlyHMSM(0, 0, 1, 0);
            OSFlagPost(keypadEnFlagGrp, 0x01, OS_FLAG_SET, &err);
        }


        DispClrLine(0);                                                           (8)
        for (i = 0; i < 3; i++) {                                                 (9)
            DispStr(0, 0, KeypadEnStr);
            OSTimeDlyHMSM(0, 0, 0,500);
            DispClrLine(0);
            OSTimeDlyHMSM(0, 0, 0,500);
```

```
        }

        aboutStrPtr = aboutStr;

        for (i = 15; i >= 0; i--) {                                          (10)
            if (*aboutStrPtr != '\0') {
                DispStr(0, i, aboutStrPtr);
                OSTimeDlyHMSM(0, 0, 0, 100);
            }
        }

        while ((aboutStr + sizeof(aboutStr) - aboutStrPtr) >  16) {          (11)
            DispStr(0, 0, aboutStrPtr++);
            OSTimeDlyHMSM(0, 0, 0, 100);
        }

        for (i = 15; i >= 0; i--) {                                          (12)
            if (*aboutStrPtr != '\0') {
                DispStr(0, 0, aboutStrPtr++);
                DispChar(0, i, ' ');
                OSTimeDlyHMSM(0, 0, 0, 100);
            }
        }

        DispClrLine(1);
        OSFlagPost(keypadEnFlagGrp, 0x01, OS_FLAG_CLR, &err);               (13)

        while (err != OS_NO_ERR) {                                           (14)
            OSTimeDlyHMSM(0, 0, 1, 0);
            OSFlagPost(keypadEnFlagGrp, 0x01, OS_FLAG_CLR, &err);
        }

        DispClrScr();                                                        (15)
        for (i = 0; i < 3; i++) {                                            (16)
            DispStr(0, 0, KeypadDisStr);
            OSTimeDlyHMSM(0, 0, 0,500);
            DispClrLine(0);
            OSTimeDlyHMSM(0, 0, 0,500);
        }
    }
}
```

L2-3(1) Define constant strings that will be displayed on the LCD. Strings declared with the ‘const’ keyword will be placed into Flash memory and not in RAM.

L2-3(2) Initialize **µC/LCD**. Generally, if more than 1 task utilizes a particular module, it should be initialized prior to either of those tasks running. A good place to initialize such modules would be in the startup task. In this particular case, access to the LCD screen is protected by an OS flag group, therefore, since the LCD_TestTask() is the primary owner of the LCD, initialization occurs within this task, however, it could have been done elsewhere.

L2-3(3) Clear the LCD screen.

L2-3(4) Display the ‘Welcome’ message two lines at a time with a two second delay between screen updates.

L2-3(5) Clear the bottom line of the LCD.

L2-3(6) At this point, this task no longer requires both lines of the LCD. Signal the `keypadRdTask()` to awaken it so that it may read the keypad and show which key is being pressed on the bottom row of the LCD.

L2-3(7) Check for flag posting errors. This code is optional since no errors should occur during the posting of the flag. If an error does occur, the application will attempt to repost the flag every second until successful.

L2-3(8) Clear the top row of the LCD while the `keypadRdTask()` is utilizing the bottom row.

L2-3(9) Flash the 'Keypad enabled' message three times with a half second delay in between.

L2-3(10) Begin scrolling the 'about' message from right to left. This short loop shifts the message by one character until the white space to the left of the string has been filled by incoming characters.

L2-3(11) Once the string has filled the top row of the LCD, continue to shift the string left to create a scrolling effect until the end of the string is near.

L2-3(12) Shift the remaining characters off of the LCD and fill the training characters with spaces to have them appear empty. This gives the illusion that the string is scrolling off of the LCD.

L2-3(13) Clear the LCD ownership flag indicating to the `keypadRdTask()` that control of the LCD is being returned to the `LCD_TestTask()`. The `keypadRdTask()`will continue to execute until it wraps around the task body and pends on the flag group.

L2-3(14) Check for errors while posting to the flag group. This code is optional since no errors should occur while posting to the flag group, however, checking for errors is of course best practice. If an error does occur, the application will attempt to repost the flag every second until successful.

L2-3(15) Clear both rows of the LCD.

L2-3(16) Flash the 'keypad disabled' string three times with a half second in between screen updates.

Listing 2-4, SevenSegTask()

```
static  void  SevenSegTestTask (void *p_arg)
{
    CPU_INT16U  num;


   (void)p_arg;

    SevenSegDisp_Init();                                                                    (1)

    num = 0;
    while (DEF_TRUE) {
        SevenSegWrite(num);                                                                 (2)
        num = ((num + 1) % 10000);                                                          (3)
        OSTimeDlyHMSM(0, 0, 0, 10);                                                         (4)
    }
}
```

L2-4(1) Initialize the seven segment display BSP. The seven segment display BSP initiates a periodic ECT channel interrupt which writes the specified value to the seven segment display blocks every time the interrupt occurs. This functionality is independent of calling `SevenSegWrite()` which only updates the value to be displayed until the next call to `SevenSegWrite()`. The ECT channel used may be changed within *app_cfg.h*.

L2-4(2) Write an initial starting value to the seven segment display.

L2-4(3) Increment the number to be displayed next by one, keeping it between 0 and 9999.

L2-4(4) All **µC/OS-II** tasks must either enter an infinite loop 'waiting' for some event to occur or terminate itself. In this case, we wait for time to expire as the 'event'. This is accomplished by calling `OSTimeDlyHMSM()`with a timeout of 10 milliseconds.

Listing 2-5, KeypadRdTask()

```
static  void  KeypadRdTask (void *p_arg)
{
    CPU_INT08U  key;
    CPU_INT08U  out_str[17];
    CPU_INT08U  key_map[] = {'1', '2', '3', 'A',
                             '4', '5', '6', 'B',
                             '7', '8', '9', 'C',
                             '*', '0', '#', 'D'
                             };
    CPU_INT08U  err;


   (void)p_arg;

    KeypadInitPort();                                                        (1)

    keypadEnFlagGrp = OSFlagCreate(0, &err);                                 (2)

    while (err != OS_NO_ERR) {
        OSTimeDlyHMSM(0, 0, 1, 0);
        keypadEnFlagGrp = OSFlagCreate(0, &err);
    }

    OSFlagPend(keypadEnFlagGrp, 0x01, OS_FLAG_WAIT_SET_ALL, 0, &err);        (3)

    DispClrLine(1);

    while (DEF_TRUE) {
        OSFlagPend(keypadEnFlagGrp, 0x01, OS_FLAG_WAIT_SET_ALL,0, &err);     (4)
        key = KeypadReadPort();                                              (5)
        if (key == 0xFF) {                                                   (6)
            err = sprintf(out_str, "Keypad is IDLE");
        } else {
            err = sprintf(out_str, "You Pressed: %c", key_map[key]);
        }

        DispStr(1, 0, out_str);                                              (7)
        OSTimeDlyHMSM(0, 0, 0, 100);                                         (8)
    }
}
```

L2-5(1) Initialize the keypad BSP.

L2-5(2) Create a flag group used to signal between the `LCD_TestTask()` and the `keypadRdTask()` when access to the bottom row of the LCD is permitted.

L2-5(3) Wait (block) until the `LCD_TestTask()` posts the flag.

L2-5(4) Check the flag to ensure access to the LCD is still permitted. If the flag remains clear, then the task will continue into the task body. Upon each iteration of the loop, the flag is checked to ensure that access to the LCD has not been revoked by the `LCD_TestTask()`.

L2-5(5) Read the keypad. If a button is pressed, a value between 0 and 15 will be returned. Otherwise, 0xFF is returned.

L2-5(6) If no keys have been pressed, create the string, 'The keypad is IDLE'. Otherwise, look up which key character is pressed within the key map array and create the string, 'You Pressed <char>'.

L2-5(7) Print the correct string to the bottom row of the LCD.

L2-5(8) Repeat the keypad polling process every 100 milliseconds until blocked by the `Keypad_TestTask()`.

2.02 Example Code, app_cfg.h

This file is used to configure:

- the **μC/OS-II** task priorities of each of the tasks in your application
- the stack size for each task
- **μC/LCD**
- some aspects of **μC/Probe**

2.03 Example Code, includes.h

includes.h is a 'master' header file that contains `#include` directives to include other header files. This is done to make the code cleaner to read and easier to maintain. It is recommended that additional include files be included from within *includes.h*.

2.04 Example Code, os_cfg.h

This file is used to configure **μC/OS-II** and defines the maximum number of tasks that your application can have, which services will be enabled (semaphores, mailboxes, queues, etc.), the size of the idle and statistic task and more. In all, there are about `60` or so `#defines` that you can set in this file. Each entry is commented and additional information about the purpose of each `#define` can be found in the **μC/OS-II** book. `os_cfg.h` assumes you have **μC/OS-II** V2.85 or higher but also works with previous versions of **μC/OS-II**.

3.00 Board Support Package (BSP)

BSP stands for Board Support Package and provides functions to encapsulate common I/O access functions in order to make it easier for you to port your application code. In fact, you should be able to create other applications using the Dragon12-Plus evaluation board and reuse these functions thus saving you a lot of time. Many of the provided functions are backward compatible with the standard Dragon12.

The BSP performs the following functions:

- Determine the MC9S12 CPU clock and bus frequencies
- Configure the LED I/Os for the Dragon12-Plus EVB.
- Configuration and handling of the **μC/OS-II** tick timer
- Configuration and handling of the **μC/Probe** measurement timer

The BSP for the Dragon12-Plus is found in the follow directory.

\Micrium\Software\EvalBoards\Freescale\MC9S12DG256B\Wytec ragon12\Metrowerks\Paged\BSP

This directory contains:

bsp.c
bsp.h
keypad.c
keypad.h
sevenSegDisp.c
sevenSegDisp_OS.c
sevenSegment.s
sevenSegDisp.h
nvm.c
nvm.h
Vectors.c

3.02 Board Support Package, bsp*.*

We will not be discussing every aspect of the BSP but only cover topics that require special attention.

Your application code must call `BSP_Init()` to initialize the BSP. `BSP_Init()` in turn calls other functions when necessary.

Listing 3-1, BSP_Init()

```
void BSP_Init (void)
{
    INT32U  sys_clk_frq;

#if PLL_EN > 0                                                    (1)
    PLL_Init();                                                   (2)
    BSP_SetECT_Prescaler(4);                                      (3)
```

```
#endif

    OSTickISR_Init();                                               (4)
    LED_Init();                                                     (5)

    sys_clk_frq  =  BSP_CPU_ClkFreq();                              (6)
    sys_clk_frq /=  1000;                                           (7)
    Flash_Init (sys_clk_frq);                                       (8)
}
```

L3-1(1) If `PLL_EN` is configured to 1 within `BSP.h`, the processor PLL will be initialized. The conditional compilation for PLL initialization is necessary since the ECT is dependent on system bus frequency. The ECT timer, TCNT, is a 16 bit up counter. The match register used to create the **µC/OS-II** time tick is also a 16 bit value. If the timer operates too quickly, then the number of time ticks necessary to obtain the desired `OS_TICKS_PER_SEC` (see `os_cfg.h`) will overflow during the call to `OSTickISR_Init()`. Therefore, the ECT prescaler must be increased from the default value when the PLL is active.

L3-1(2) This function initializes the on chip PLL. First, the multiplier and divider are configured, then the PLL is enabled, and finally, the system clock is switched from the main oscillator to that of the PLL output.

L3-1(3) Adjust the ECT prescaler if the PLL is enabled to prevent an overflow of `OSTickCnts` during the call to `OSTickISR_Init()`.

L3-1(4) Initialize the selected ECT channel for use with the **µC/OS-II** time tick interrupt. The code for this function is described below.

L3-1(5) Initialize the general purpose I/O pins used for controlling the onboard LEDs.

L3-1(6) Determine the CPU clock frequency in Hz during run time. It is highly recommended that application code make use of this function in order to program system dividers during runtime. This prevents the user from having to change all hard coded divider values should the clock frequency need to be modified at a later time.

Note: The system bus frequency is the CPU clock frequency divided by 2. Some module input clocks use the CPU clock as a reference while others use the bus clock. Be sure to determine the correct clock for the module being initialized and use `BSP_CPU_ClkFreq() / 2` when necessary.

L3-1(7) Convert the CPU clock frequency from Hz to KHz.

L3-1(8) Initialize the Flash memory access dividers. Steps 6 through 8 are optional and are not present in the Dragon12-Plus BSP. However, including the *nvm.c* and *nvm.h* files and adding these lines, either within the BSP, or another part of the application will allow the user to change the content of either Flash memory or EEPROM during run-time.

Listing 3-2, OSTickISR_Init ()

```
static void  OSTickISR_Init (void)
{
    INT32U cpu_frq;
    INT32U bus_frq;
    INT8U  ECT_Prescaler;


    cpu_frq = BSP_CPU_ClkFreq();                                    (1)
    bus_frq = cpu_frq / 2;                                          (2)

    ECT_Prescaler = TSCR2 & 0x07;                                   (3)

    ECT_Prescaler = (1 << ECT_Prescaler);                           (4)

                                                                    (5)
    OSTickCnts    = (INT16U)((bus_frq / (ECT_Prescaler * OS_TICKS_PER_SEC)) - 1);

#if OS_TICK_OC == 0                                                 (6)
    TIOS  |= 0x01;                                                  (7)
    TC0   = TCNT + OSTickCnts;                                      (8)
    TIE |= 0x01;                                                    (9)
#endif

#if OS_TICK_OC == 1
    TIOS  |= 0x02;
    TC1   = TCNT + OSTickCnts;
    TIE |= 0x02;
#endif

#if OS_TICK_OC == 2
    TIOS  |= 0x04
    TC2   = TCNT + OSTickCnts;
    TIE |= 0x04
#endif

#if OS_TICK_OC == 3
    TIOS  |= 0x08
    TC3   = TCNT + OSTickCnts;
    TIE |= 0x08
#endif

#if OS_TICK_OC == 4
    TIOS  |= 0x10;
    TC4    = TCNT + OSTickCnts;
    TIE |= 0x10;
#endif

#if OS_TICK_OC == 5
    TIOS  |= 0x20;
    TC5    = TCNT + OSTickCnts;
    TIE |= 0x20;
#endif

#if OS_TICK_OC == 6
    TIOS  |= 0x40;
    TC6    = TCNT + OSTickCnts;
    TIE |= 0x40;
#endif

#if OS_TICK_OC == 7
    TIOS  |= 0x80;
    TC7    = TCNT + OSTickCnts;
    TIE |= 0x80;
#endif

    TSCR1 = 0xC0;                                                  (10)
}
```

L3-2(1) Get the CPU operating frequency in Hz

L3-2(2) Divide the CPU frequency by 2 in order to obtain the bus clock frequency in Hz. This value is used to calculate the correct number of timer increments for the desired OS Tick rate.

L3-2(3) Determine the ECT prescaler value. The ECT prescaler acts as a divider to the input clock of the ECT. The higher the ECT prescaler, the more slowly TCNT, the ECT up counter register, increments. The ECT prescaler is an important piece of information when calculating required timer channel match value.

L3-2(4) Convert the ECT prescaler register value into the decimal equivalent suitable for mathematical calculations. (E.g. Turn the bit pattern '01' into a prescaler value of 2 and so on).

L3-2(5) Compute the number of timer increments necessary to generate the desired **μC/OS-II** Tick rate.

L3-2(6) If `OS_TICK_OC` in *bsp.h* is defined as 4, then configure TC4 as the **μC/OS-II** tick source.

L3-2(7) Configure the desired timer channel as an output compare.

L3-2(8) Write the match register with the current value of the ECT counter (TCNT) plus the number of ticks until the next desired match.

L3-2(9) Enable output compare interrupts on the desired ECT channel.

L3-2(10) Start the timer.

Listing 3-3, Tmr_TickISR_Handler()

```
void  OSTickISR_Handler (void)
{
#if OS_TICK_OC == 0                                                    (1)
    TFLG1 |= 0x01;                                                     (2)
    TC0   += OSTickCnts;                                               (3)
#endif

#if OS_TICK_OC == 1
    TFLG1 |= 0x02;
    TC1   += OSTickCnts;
#endif

#if OS_TICK_OC == 2
    TFLG1 |= 0x04;
    TC2   += OSTickCnts;
#endif

#if OS_TICK_OC == 3
    TFLG1 |= 0x08;
    TC3   += OSTickCnts;
#endif

#if OS_TICK_OC == 4
    TFLG1 |= 0x10;
    TC4   += OSTickCnts;
#endif
```

```
#if OS_TICK_OC == 5
    TFLG1 |= 0x20;
    TC5   += OSTickCnts;
#endif

#if OS_TICK_OC == 6
    TFLG1 |= 0x40;
    TC6   += OSTickCnts;
#endif

#if OS_TICK_OC == 7
    TFLG1 |= 0x80;
    TC7   += OSTickCnts;
#endif

    OSTimeTick();                                                      (4)
}
```

This function is called from an assembly interrupt service routine which informs **μC/OS-II** of the interrupt and calls the 'C' code interrupt handler. See `os_cpu_a.s` and the section labeled "Creating Interrupt Service Routines" for more information.

L3-3(1) If `OS_TICK_OC` is configured to 4

L3-3(2) Clear the interrupt source

L3-3(3) Adjust the timer channel match register so that a new time tick will occur after `OSTickCnts` additional counts.

L3-3(4) Call `OSTimeTick()` to inform **μC/OS-II** of the clock tick.

The ECT generates match interrupt when the up-counter value reaches the value stored within the timer channel match register. After an interrupt occurs, the match register is incremented to the next value for which a time tick interrupt is desired. The timer is allowed to free-run and overflow without error when necessary.

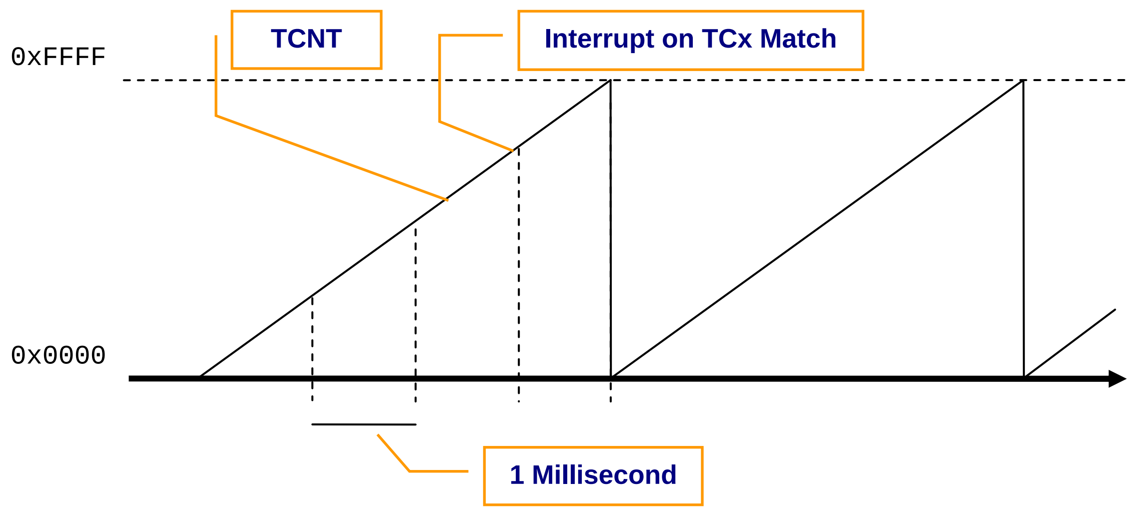


Figure 3-1, OS Tick Timer Operation

When the selected Timer issues an interrupt, the processor vectors to `OSTickISR()` which has been specified in *vectors.c* and is located within *os_cpu_a.s*. The ISR handler performs the necessary OS handling steps and then calls a 'C' handler function named `OSTickISR_Handler()` located within *bsp.c* as described above in Listing 3-3.

You should note that ALL of your ISRs should be written in assembly where OS related processing may take place before calling an interrupt handler function of the form '`interrupt void MyISR_Handler(void)`'. See the section labeled 'Creating Interrupt Service Routines' for more information.

3.03 Configuring the PLL

The PLL is an on chip peripheral capable of boosting the processor clock and bus frequencies higher than the frequency provided by the supplied oscillator across the XTAL pins of the MCU. Before attempting to reconfigure the PLL from *bsp.h* you should consult your MC9S12 derivative datasheet and understand the MCU's absolute maximum ratings. The absolute maximum ratings must be followed in order to prevent the possibility of damaging the device.

The MC9S12DG256 has a maximum processor clock (`SYSCLK`) of 50MHz. The bus clock (`BUSCLK`) is <u>always</u> ½ of the processor clock and must never exceed 25 MHz. The oscillator supplied on the Dragon12-Plus is 8MHz which means that the highest stable clock frequency for this EVB is 48MHz with a 24MHz bus frequency.

<u>Note</u>: The input oscillator frequency is automatically doubled before entering the PLL. Therefore, the highest possible PLL multiplier is 4, which effectively multiplies the 16MHz (8MHz * 2) input frequency by 4, this creating a 48MHz CPU clock frequency.

The PLL may be configured by adjusting the following macros within *bsp.h*:

```
OSCFREQ
PLL_EN
PLL_CLK_MUL
PLL_CLK_DIV
```

The output frequency is computed by the following formula:

```
((OSCFREQ * 2) * (PLL_CLK_MUL + 1) / (PLL_CLK_DIV + 1)
```

Where `OSCFREQ` is the frequency of the oscillator attached to the XTAL pins of the MCU. In the case of the Dragon12-Plus, OSCFREQ equals 8,000,000 Hz.

The PLL may be disabled by setting the value of `PLL_EN` to 0. The example provided is capable of running with the PLL either enabled or disabled. High performance applications may wish to enable the PLL, while power aware devices such as portable electronics may wish to run the device with the PLL disabled or with an increased divider thereby lowering the overall frequency below the supplied oscillator frequency. In general, lower clock speeds require less operating power. The operating frequency of the MC9S12DG256 must never fall below 8MHz with the PLL enabled.

When enabling the PLL on the MC9S12DG256, the highest possible value for `PLL_CLK_MUL` is 3, while the lowest possible value of `PLL_CLK_DIV` is 0.

Plugging these register values into the above equation yields the following:

```
SYSCLK = ((8,000,000 * 2) * (3 + 1) / (0 + 1)
       =   (48MHz * 1) / 1 = 48MHz

BUSCLK =  SYSCLK / 2       = 24MHz
```

The BSP function `BSP_CPU_ClkFreq()`yields the current SYSCLK frequency and is the preferred method for determine the system operating frequency during run-time.

Note: BSP_CPU_ClkFreq()returns a 32 bit unsigned integer representation of the SYSCLK frequency. Dividing this value by 2 will yield the BUSCLK frequency. It is recommended that users call this function before programming peripheral clock dividers so that the dividers need not be re-evaluated should the clock frequency be adjusted at a later time.

This method is used when computing the **μC/OS-II** tick number of counts during initialization, and when computing the baud rate for **μC/Probe**. It is important to note that most, but not all, MC9S12 peripherals use the BUSCLK as a reference clock source. An example of divider initialization based on an unknown operating frequency may be performed as follows:

Listing 3-4, Set_SCI_BaudRate()

```
void  Set_SCI_BaudRate (INT32U baud)
{
    CPU_INT32U  baudDiv;                                          (1)


    baudDiv  =  BSP_CPU_ClkFreq();                                (2)
    baudDiv /= (2 * baud * 16);                                   (3)

    SCI0BDH = baudDiv >> 8;                                       (4)
    SCI0BDL = baudDiv & 0xFF;                                     (5)
}
```

L3-4(1) Declare a 32 bit unsigned variable to hold the current SYSCLK frequency.

L3-4(2) Call BSP_CPU_ClkFreq() in order to obtain the current SYSCLK frequency.

L3-4(3) Divide the SYSCLK frequency by 2 in order to obtain the BUSCLK frequency. Note: the SCI's reference clock is derived from BUSCLK. Next divide the BUSCLK frequency by 16 to account for the SCI over sampling. The is mentioned in the SCI block documentation under the section for computing the SCI baud rate. Finally, divide by the desired baud rate to achieve the SCI divider that corresponds to the specified baud rate and the current MCU operating frequency. If you look closely, the division by 2, 16, and the desired baud was optimized in order to reduce the amount of truncation. Truncation on smaller dividers such as 6.78 (for 115,200 baud given BUSCLK = 24MHz) can be significant. The actual baud rate after truncation would be (BUSCLK / (2 * 16 * 6) = 125,000 baud which corresponds to an 8% error rate, which is acceptable for many UARTS. If necessary, take the ceiling of fractional dividers. It's better to operate too slowly than too fast.

L3-4(4) Write the high byte of the divider to the baud rate high byte register.

L3-4(5) Write the low byte of the divider to the baud rate low byte register.

3.04 Vectors.c

vectors.c contains the interrupt vector table for the application. The interrupt vector table is necessary so that the processor knows the address of the interrupt service routine to jump to when a specific interrupt occurs. Failure to properly plug the interrupt vector table with the address of a valid handler may cause the application to crash. If a wrong, but valid, interrupt handler address is specified for vector number 'n' and the interrupt occurs, the interrupt source will not be cleared and the processor will execute the same interrupt service routine indefinitely.

Care should be taken when working with the interrupt vector table.

For convenience, dummy interrupt service routines have been provided for all 64 vectors. This does not include the reset vector since its value must always be set correctly. When an interrupt vector is not in use, the dummy ISR for that vector should be plugged. In the case of a spurious interrupt, the processor will vector to the dummy ISR and loop indefinitely. Should this occur, you may be able to debug the application and catch the processor in the dummy interrupt service routine thus identifying the source of the spurious interrupt. The correct action may then be taken to correct the application to prevent this type of error in the future.

When plugging the interrupt vector table with a new vector, a 'C' prototype in the form of:

```
extern void near  MyISR(void);
```

must be provided at the top of the *vectors.c* file. The name of the ISR may then be plugged into the correct location of the interrupt vector table.

The following vectors are used by **µC/OS-II** and should not be modified:

Vector 8: Standard Timer Channel 0. This ECT channel functions as a periodic interrupt for driving the seven segment display.

Vector 15: Standard Timer Channel 7. This may be adjusted to one of the other Standard Timer Channel vectors if desired. See the section labeled "Porting to Other MC9S12 Derivatives" for more information.

Vector 21: SCI1. The selected communication port for **µC/Probe**. Vector 20, SCI0 may be used instead of SCI1 if desired. However, the serial monitor uses SCI0 by default therefore loading and debugging would have to occur using a BDM in order to free up the additional SCI. If the **µC/Probe** default SCI port is changed, then *prob_com_cfg.h* will need to be adjusted accordingly.

3.05 Creating Interrupt Service Routines

All interrupt service routines must contain a short assembly routine. The address of the assembly routine is used to plug the interrupt vector table, while the content is designed to notify **µC/OS-II** of the interrupt and call the user supplied interrupt handler written in either assembly or 'C' code.

The prototype specified at the top of *vectors.c* (See section 3.04 above) is the 'C' code prototype for the following assembly interrupt service routine. It is this prototype that allows you to plug the interrupt vector table with the name (address) of the ISR from 'C'.

As a reminder, the prototype is written as follows:

```
extern void near  MyISR(void);
```

Of course, the name of the ISR would change each time a new ISR is declared since two ISR's of the same name cannot exist in the system simultaneously.

The format of an interrupt service routine is as follows:

Listing 3-5, MyISR

```
NON_BANKED:         section                                     (1)

PPAGE:              equ $0030                                   (2)

xdef                MyISR_Handler                               (3)

xref                OSIntExit                                   (4)
xref                OSIntNesting                                (5)
xref                OSTCBCur                                    (6)
xref                OSView_RxTxISRHandler                       (7)

MyISR:
    ldaa    PPAGE                                               (8)
    psha                                                        (9)

    inc     OSIntNesting                                       (10)

    ldab    OSIntNesting                                       (11)
    cmpb    #$01                                               (12)
    bne     MyISR1                                             (13)

    ldy     OSTCBCur                                           (14)
    sts     0,y                                                (15)

MyISR1:
    call    OSTickISR_Handler                                  (16)

    cli                                                        (17)
    call    OSIntExit                                          (18)

    pula                                                       (19)
    staa    PPAGE                                              (20)

    rti                                                        (21)
```

L3-4(1) Force the contents of the assembly file, perhaps named: `myisr_a.s`, into NON_BANKED memory. This is critical since the processor only has a 16 bit address bus. Vectors that are accidentally placed into banked memory will have a 24 bit address (8 bit page number + 16 bit address) and will overflow the slot in the interrupt vector table.

L3-4(2) Define the address of the PPAGE register. This register is memory mapped and located at address 0x30 on the MC9S12DG256 MCU.

L3-4(3) XDEF is a Codewarrior assembly directive for prototyping external functions. This directive is equivalent to 'extern' in 'C' and allows the assembler to find the address of the ISR handler specified below on line item (16). The name being XDEF'd should match the name of your ISR handler whether it is written in assembly or 'C' code. This directive is not necessarily portable to other assemblers.

L3-4(4) (4), (5), (6), and (7), are external references to variables defined in 'C'. These variables are referenced from the context of the assembly ISR and must therefore be declared external such that they are visible to the assembler and ISR file. This directive is not necessarily portable to other assemblers.

L3-4(8) Obtain a copy of the PPAGE register. This register must be saved because the **μC/OS-II** is operating under the BANKED memory model.

L3-4(9) Store the PPAGE register on the stack of the task that was interrupted.

L3-4(10) Increment `OSIntNesting`. This notifies **μC/OS-II** that at least one interrupt is in progress and that the scheduler should not schedule any new tasks to run until all nested interrupts have completed (e.g. `OSIntNesting` equals 0).

L3-4(11) Load a copy of `OSIntNesting` from memory into a register so a comparison may be made.

L3-4(12) Check `OSIntNesting` to see if its value is 1. If so, then this is the only interrupt in progress and no nested interrupts are pending completion.

L3-4(13) If interrupt have been nested, skip storing the current tasks stack pointer back into its task control block and jump to `MyISR1`. Note: the name of the ISR and the labels used within it must be changed for each new ISR implemented in the system. For convenience, the number '1' is added to the end of the ISR name in order to create a unique and convenient label to jump to.

L3-4(14) If no interrupts have been nested then the scheduler is free to schedule a new task when the ISR completes. Therefore the address of the current task TCB (Task Control Block) is obtained.

L3-4(15) The stack pointer of the interrupted task is stored within its own TCB should the scheduler perform a context switch at the end of the ISR.

L3-4(16) Call the user defined ISR handler. Generally the ISR handler is defined and prototyped in 'C'.

L3-4(17) Re-enable interrupts. This is optional, and allows interrupts to nest one another. A performance gain may be difficult to obtain and in most cases, nested interrupts are not necessary.

L3-4(18) Call `OSIntExit()`. This informs **μC/OS-II** about the end of the interrupt. This is effectively the same as decrementing `OSIntNesting` however, the scheduler is also invoked and if a context switch is required, `OSIntExit()` will not return.

L3-4(19) If a context switch is not necessary, obtain the copy of PPAGE saved at the beginning of the ISR

L3-4(20) Restore the PPAGE register.

L3-4(21) Return to the interrupted task.

4.00 Porting to Other MC9S12 Derivatives

Due to the similarities between various MC9S12 derivatives, it is easy to port the sample application from one derivative to another. The following steps must be performed in order to switch MCU derivatives:

Porting to different MC9S12 derivatives:

1) Navigate to the project directory and open the project file using Codewarrior.

2) Replace the processor header files in the source tree with those from the desired derivative. Adjust includes.h accordingly.

3) Replace the CMD directory contents with the command files from a project built for the derivative of your choice.

4) Obtain a .prm file from a sample project belonging to the derivative of your choice. The .prm file contains linker configuration directives for the desired MCU derivative. Replace existing the linker .prm located in the below directory with the .prm of the new derivative.

   Note: Generally Codewarrior defines the Startup vector in the .prm file. All interrupt vector references MUST be removed from the .prm in favor of those already specified in *vectors.c*.

4) Update BSP.c functions for LED_On(), LED_Off(), LED_Toggle() etc... to match your hardware configuration if required.

6) Adjust the macro `OSCFREQ` within *bsp.h* to account for a different oscillator frequency if applicable.

5) Ensure that the PLL settings within *bsp.h* are suitable for use within the new derivative. If you are unsure, disable the PLL temporarily until the proper settings can be determined.

Caveats:

1) *vectors.c* is provided as is and is assumed to be correct for some MC9S12 derivates. Vectors can be added by prototyping the assembly ISR handler as an external at the top of the file, and then plugging the correct array location with the name of the ISR routine. See section 3.04 labeled “Vectors.c” for more information.

2) The example provided assumes the use of ECT TC7 for the OS Ticker. If TC7 is not available, this may be changed by adjusting the macro named "OS_TICK_OC" within *bsp.h* and by adjusting *vectors.c* and placing "OSTickISR" in the desired vector location.

3) Start12.c may need to be replaced with an equivalent file from a project built for the derivative of your choice.

4.01 Additional Reading

1. MicroC/OS-II, "The Real Time Kernel".

The following application notes are relatively short and provide detailed concept and usage examples for **µC/OS-II**. These application notes have been bundled with AN1458 for convenience.

2. AN2000, "'C' Standard'.
3. AN1002, "Mutex".
4. AN1004, "10 Minute Guide to RTOS".
5. AN1005, "Introduction to IPC" (Inter-Process Communication).
6. AN1007, "Event Flags".

The following documents may be found in the uC/OS-II documentation directory located within ***c:\Micrium\Software\uCOS-II\doc***.

7. *QuickRefChart-Color.PDF*. An short summary of all **µC/OS-II** API functions.
8. *uCOS-II-RefMan.PDF*. A detailed user manual for **µC/OS-II**.
9. *uCOS-II-CfgMan.PDF*. **µC/OS-II** configuration guide. (Related to *os_cfg.h*)

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References

MicroC/OS-II, The Real-Time Kernel, 2nd Edition
Jean J. Labrosse
CMP Technical Books, 2002
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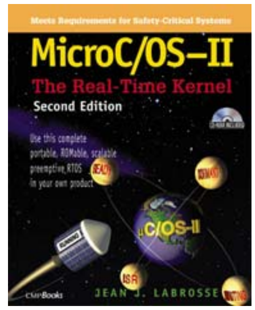

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