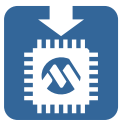
TLS4102

Getting Started with MPLAB® Harmony Framework

Lab Manual



(for Harmony v1.05)

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V0.99c June 30th 2015

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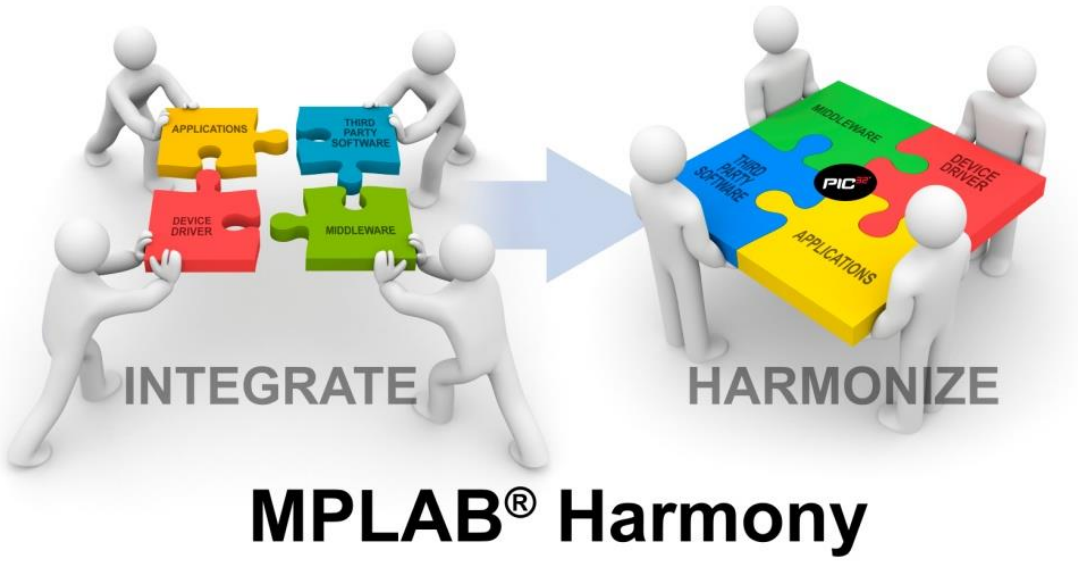

TLS4102 class : Getting started with MPLAB® Harmony Framework

Hands-on class Introduction:

In the labs you will be requested to follow specific and certain steps to configure the PIC32 MCU. Due to the limited time allotted for each lab the background details as to why each configuration is requested is not provided. Upon completion of the class labs you are encouraged to further your knowledge and understanding on the PIC32 MCU setup and configuration options.

Note: This workshop is designed to support both PIC32MZ Starter Kits:

1. PIC32MZ Embedded Connectivity Starter Kit
   part # DM320006 (PIC32MZ2048ECH144 MCU)
2. PIC32MZ Embedded Connectivity Starter Kit w/Crypto Engine
   part # DM320006-C, (PIC32MZ2048ECM144 MCU)

Hands-on Class know-how Prerequesites:

The workshop lab material assumes the attendee has prior experience with:

1. MPLAB® X IDE fundamentals
2. MPLAB based Programming/Debugging fundamentals
3. ‘C’ language programming
4. Basic knowledge on PIC32 product family

Upon completion of this workshop you will:

1. Gain a basic understanding how to create an MPLAB® X and Harmony project
2. Gain a basic understanding and foundation on MPLAB® Harmony Framework
3. Gain hands-on experience with MPLAB® Harmony Framework components
4. Gain hands-on experience with the MPLAB® Harmony Configurator Tool
5. Gain overall understanding on key benefits and features of MPLAB® Harmony

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Hardware / software installation:

Note: If you are not using a Microchip Training Center laptop, please install the following software:

PC installation

1. MPLAB® X IDE: **v3.05** (or later)
2. MPLAB® XC32 compiler : **v1.40** (or later)
3. MPLAB® Harmony **v1.05**
4. MPLAB® Harmony Configurator (MHC) plugin for MPLAB® X IDE

C:\microchip\harmony\v1_05\utilities\mhc\com-microchip-mplab-modules-mhc.nbm

5. Windows® XP or Windows® 7 PC with two USB ports
6. TeraTerm Pro or other terminal emulator program

Hardware equipment

1. PIC32MZ Embedded Connectivity Starter Kit
   part # DM320006 (without crypto engine….. PIC32MZ2048EC**H**144 MCU)
   or # DM320006-C (with crypto engine…….PIC32MZ2048EC**M**144 MCU)
2. Multimedia Expansion Board II (DM320005-2)
3. UART to USB bridge expansion board (AC320101)
4. USB pen drive (USB key) formatted with FAT, FAT16 or FAT32
5. 9V power supply
6. mini USB-to-USB cable

For Presenter only (demo labs):

1. PIC32MX USB starter kit II (ref DM320003-2) (DM320004 can also be used)
2. Multimedia Expansion Board (ref DM320005)

Move downloaded lab files into Harmony folder :

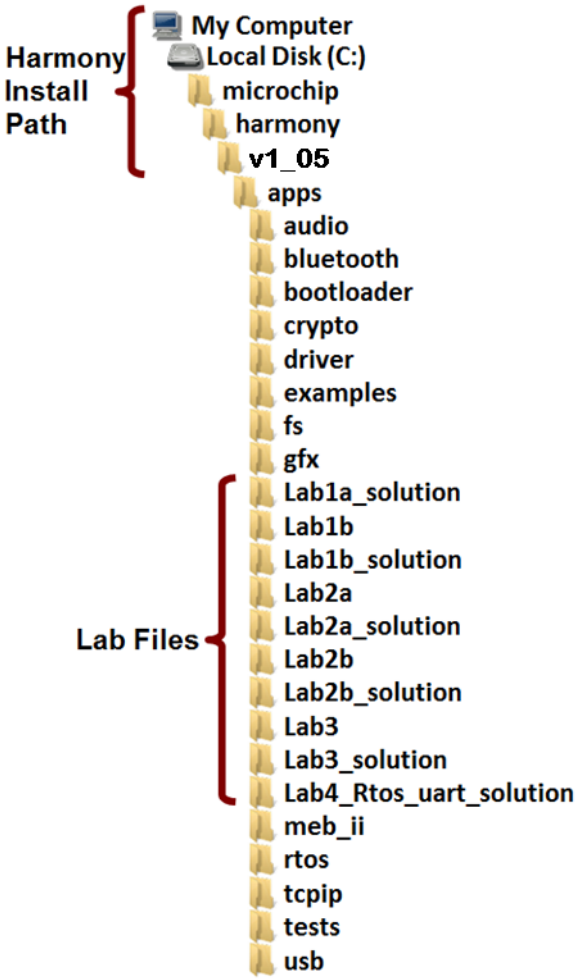
(*) for TLS4102 training center class participants see alternative installation procedure at the bottom of this page

Important!

The lab files downloaded from the Microchip Developer Help site **need to be placed in a specific directory level**, relative to the Harmony installation directory (c:/microchip/harmony/v1_xx). If this is not done, the lab projects ***will not build*** successfully because the projects won't be able to find files that have been included using relative paths.

Un-zip the files to this directory:
<harmony install path>/apps

With Harmony v1.05, the "apps" directory will look like this once you are done:



(*) TLS4102 RTC class installation

Please use the following batch file (TLS4102_Restore_v1_xx_yy.bat) in C:\MTT\TLS4102 which will cleanup any previous labs and copy fresh labs from C:\MTT\TLS4102 to C:\microchip\harmony\v1_xx_yy\apps folder

LAB 1a: Blinky LED

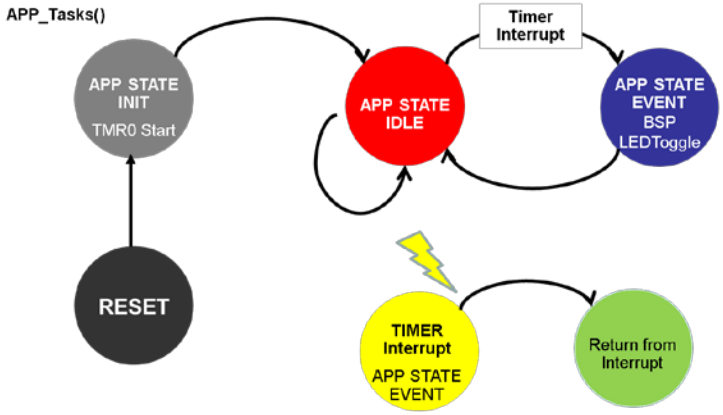
LAB 1a: Blinky LED

Purpose:

After completing Lab1a, you will have an understanding of the fundamental elements, layout, and execution model of a MPLAB® Harmony project. You will also gain hands-on knowledge in using the **MPLAB® Harmony Configurator tool (MHC)** to configure the MPLAB® Harmony project and to add features and functionality.

Overview:

In this lab you will create a simple MPLAB® Harmony project starting from scratch, beginning with opening MPLAB® X IDE. The lab result will implement a Timer Driver to blink an LED on the PIC32MZ EC Starter Kit. The lab will demonstrate basic system initialization, polled-state machine design, and use of system services.



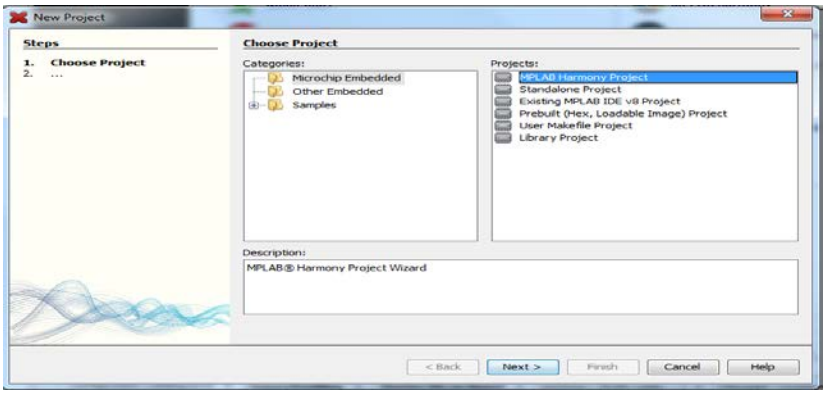
Procedure:

1. For Lab 1a, there are seven steps shown in Part 1 and Part 2. All steps must be completed **before you will be ready to build, download, and run the application**.
    - **Part 1: Create project and configure PIC32MZ**
        - Step 1 – Create MPLAB® X IDE and MPLAB® Harmony project
        - Step 2 – With MHC, set up Device Configuration
        - Step 3 – With MHC, set up BSP, and then Clocks
        - Step 4 – With MHC, set up the Timer
        - Step 5 – With MHC, Generate Code
    - **Part 2: Add Application code**
        - Step 6 – Add code in App Tasks function
        - Step 7 – In Timer interrupt handler, add code to increment (change) the app state

    Each step has a short list of requirements to guide you in the solution development. Following each set of requirements, answers are provided. You can refer to the answers as needed.

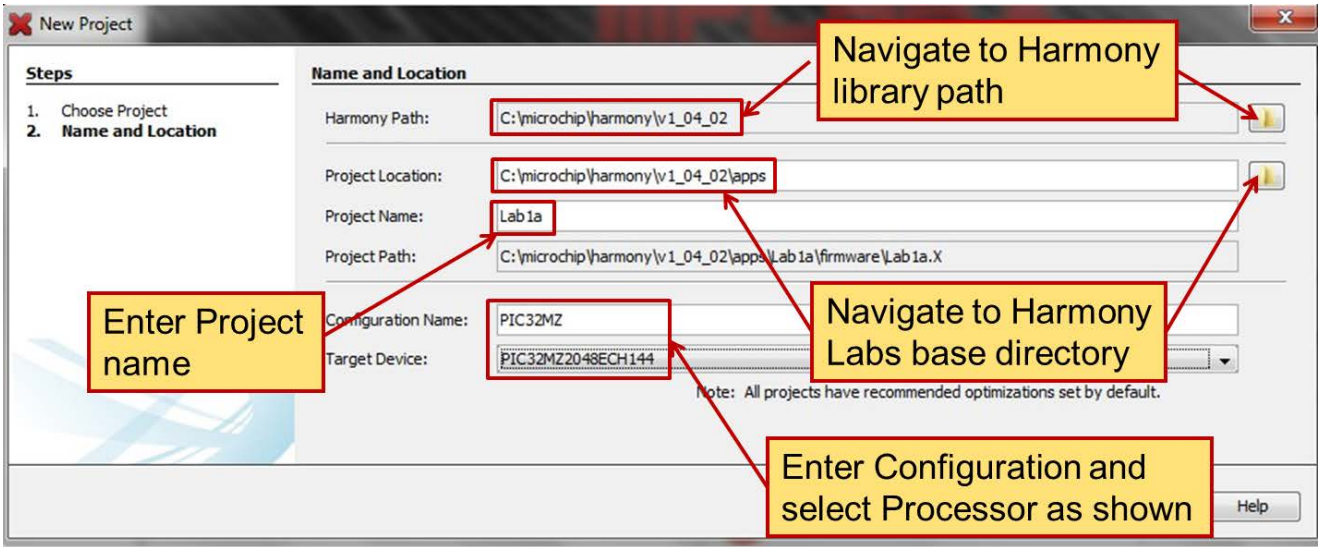
Step 1: Objective – Create MPLAB® Harmony Project

1. Start MPLAB® X IDE and create a New Project by selecting ***File*** > ***New Project***.
2. In the Categories pane of the New Project dialog, select **Microchip Embedded**.
3. In the Projects pane, select **MPLAB Harmony Project**, and then click **Next** to launch the MPLAB® Harmony Project Wizard.



4. Specify the following in the New Project dialog (see below):
   - **Harmony Path** (path to the folder containing the MPLAB Harmony framework)
   - **Project Location** (navigate where you want to put your project)
   - Enter Project Name : **Lab1a**
   - **Configuration Name** : PIC32MZ

- **Target Device** (when a valid Harmony path is selected, the device selection menu will be filled) – See Note below



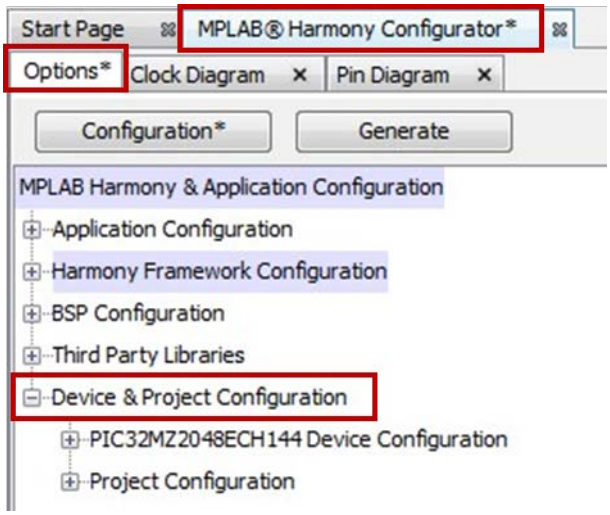
5. Push **Finish** button and a MPLAB® Harmony project will be created and the MPLAB® Harmony Configurator (MHC) window will open up in the MPLAB® X IDE. Refer to MPLAB® Harmony Help for additional information about MHC (a help window will open up when MPLAB Harmony Configurator window is started)

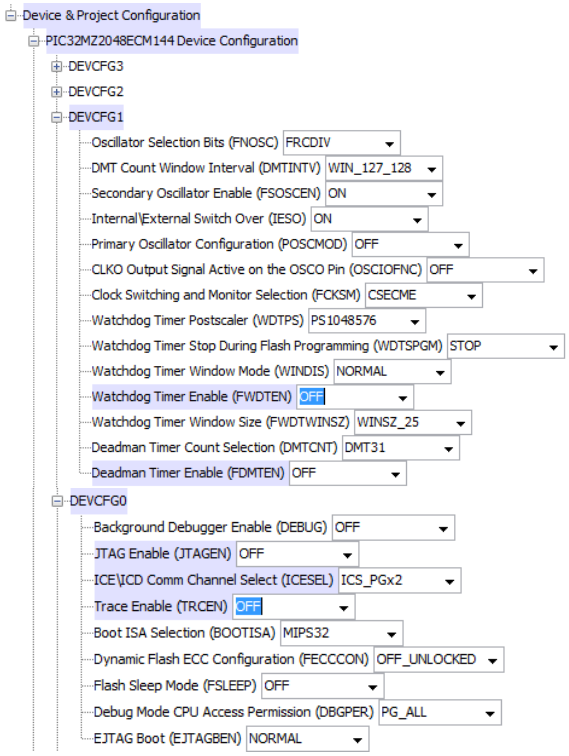
TLS4102 class : Getting started with MPLAB® Harmony Framework

Note: The labs will support either the PIC32MZ Embedded Connectivity Starter Kit, DM320006 (PIC32MZ2048ECH144 MCU) or PIC32MZ Embedded Connectivity Starter Kit w/Crypto Engine, DM320006-C, (PIC32MZ2048ECM144 MCU).

Step 2: Objective – Configure Device

1. In the central window, under **MPLAB Harmony configurator** tab, **Options** sub-tab expand the **Device & Project Configuration** tree and select the PIC32MZ2048EC**H**/(ECM)144 Device Configuration
2. **Note:** You only need to update DEVCFG1 and DEVCFG0.
    a. DEVCFG3 and DEVCFG2 – No change
    b. DEVCFG1
        i. Disable (OFF) WDT (FWDTEN)
        ii. Disable (OFF) Deadman Timer (FDMTEN)
    c. DEVCFG0
        i. Disable (OFF) JTAG (JTAGEN)
        ii. Disable (OFF) Trace (TRCEN)
        iii. Configure comm. channel pair for “ICS_PGx2” (ICESEL)





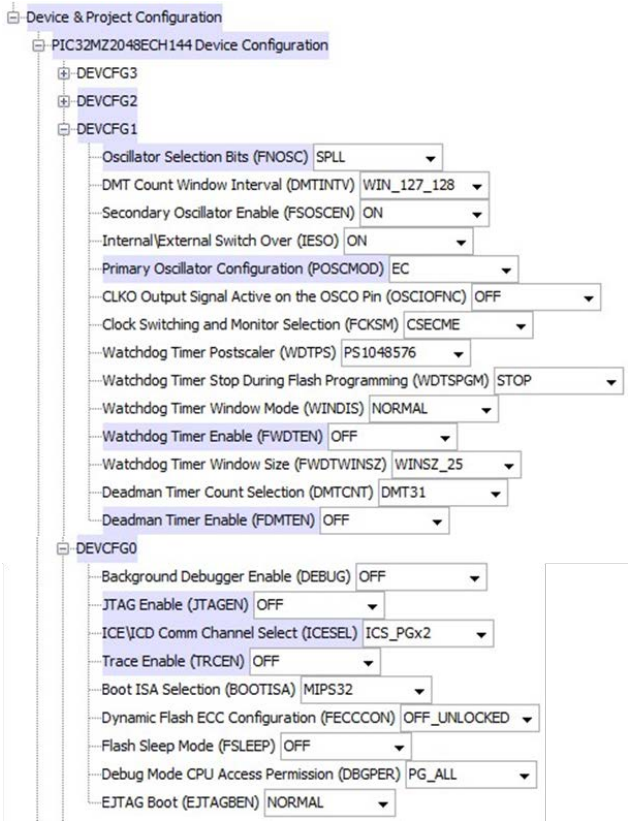
1. Note the colored background shading, when default settings are changed. This helps the user visualize what was changed in the dfault configuration
2. Before moving to step3, you may want to collapse the **Device & Project Configuration** tree

Step 2: Solution

1. Select PIC32MZ2048ECH/(ECM)144 Device Configuration
    a. DEVCFG3 – No change
    b. DEVCFG2 – No change
    c. DEVCFG1
        i. (OFF) Watchdog Timer
        ii. (OFF) Deadman Timer

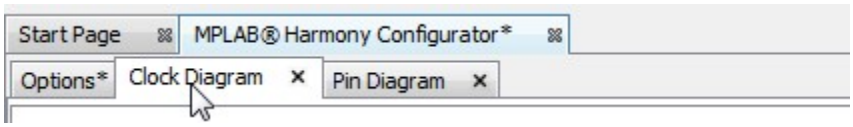
    d. DEVCFG0
        i. (OFF) JTAG Enable
        ii. ICE\ICD : ICS_PGx2
        iii. (OFF) Trace Enable

Note background shading, when default settings are changed



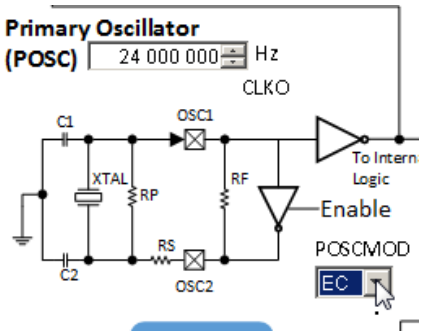
Step 3: Objective – Set BSP and Configure Clocks

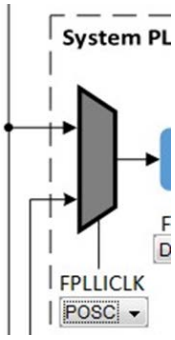
1. First, expand the **BSP Configuration** tree, check the **Use BSP?** box and select the correct BSP :
   PIC32MZ EC Starter Kit w/Multimedia Expansion Board II (MEB II)
2. Now, we want to setup the various clock options of the PIC32MZ.
   Select the **MPLAB® Harmony Clock Configuration** tab to set PIC32MZ clocks:

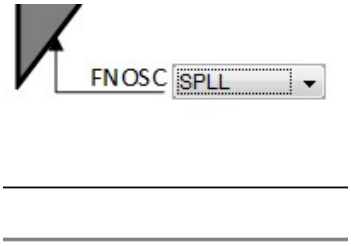


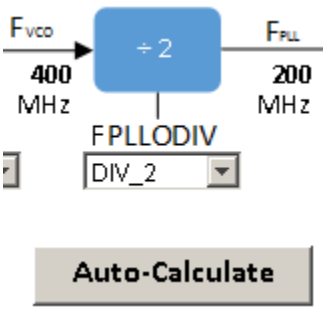
3. Use the following clock parameters :
   i. Primary Oscillator mode (**POSCMOD**) → EC mode (see **Note**).
   ii. PLL Input Clock (**FPLLICLK**) → Primary Oscillator (POSC).
   iii. Enable System PLL (**FNOSC**) → SPLL.
   iv. Push the **Auto Calculate** button in the system PLL box
   v. Confirm that **Desired System Frequency** is 200 MHz.

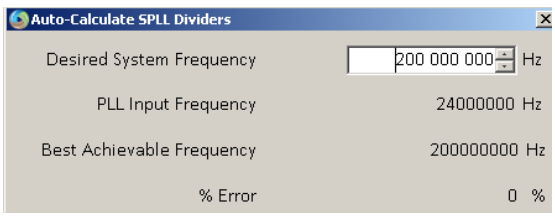
Note: The input "clock" to the PLL on the PIC32MZ EC Starter Kit is a 24 MHz clock oscillator (not a crystal oscillator).







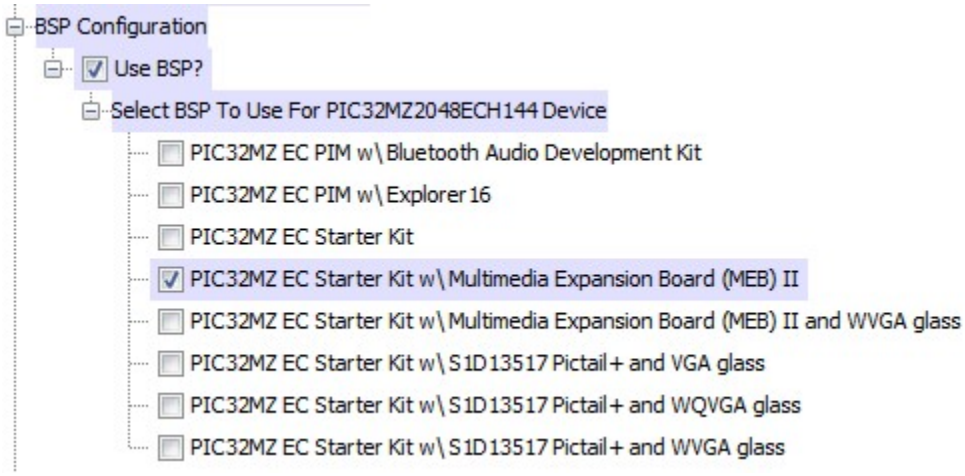




Before moving to Step4, you may want to collapse the **BSP Configuration** tree

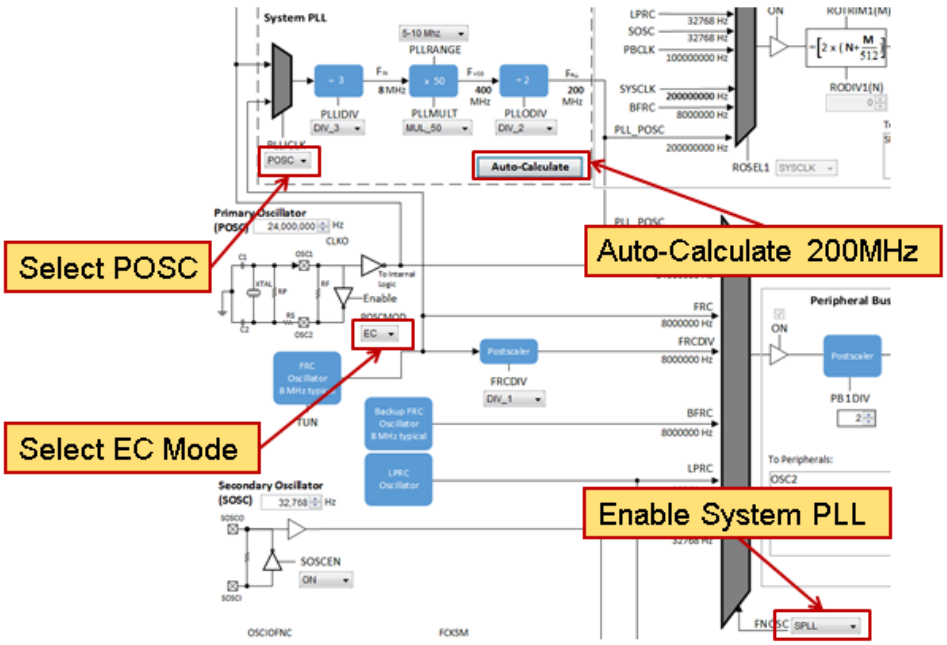
Step 3: Solution

1. Using MHC, enable and select the BSP as shown:



This board has been chosen to match the PIC32MZ hardware you are using.

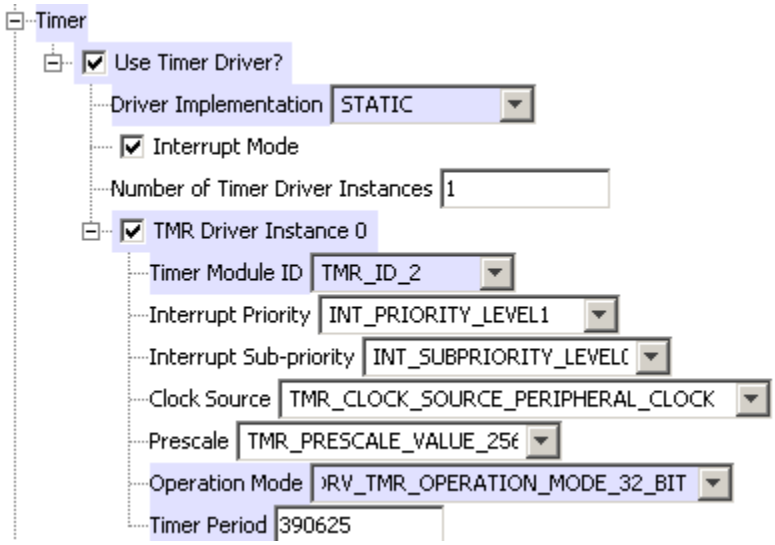
2. Using MHC, configure the PIC32MZ2048ECH/(ECM)144 clocks:
   a. Select the MPLAB® Harmony Clock Configuration tab.
   b. Select the PIC32MZ Clock Configurations as shown (steps 1 thru 4)



Step 4: Objective – Enable and Configure the Timer Driver

1. To accurately control the blink rate of the LED, we need to use the Timer Driver to generate a fixed blinking frequency.
2. Select the **MPLAB Harmony Configurator** tab
   Options sub-tab
3. Expand the **Harmony Framework Configuration** tree, expand **Drivers**, expand **Timer** tree.
   a. Check the **Use Timer Driver?** box
   b. Chose **Driver Implementation** → STATIC
   c. Check the **Interrupt Mode** box if not already checked
   d. **Number of Timer Driver Instances** → 1
   e. Select and Expand **TMR Driver Instance 0** tree option (leave default values for parameters other than below)
      i. Set **Timer Module ID** → TMR_ID_2
      ii. Set **Operation Mode** → DRV_TMR_OPERATION_MODE_32_BIT
      iii. Set **Timer Period** → xxx (see below how to calculate value for 1s).
      Make sure to press the ENTER key after entering the value

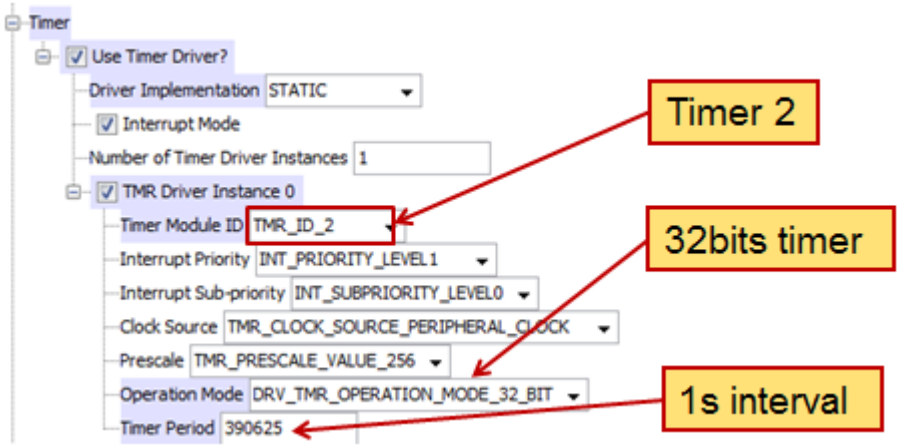
Reference information : Timer2 peripheral is on Peripheral Bus 3 (PBCLK3) and the default clock divisor for PBCLK3 is 2, giving Timer2 an input clock of 100 MHz. Since the Timer Driver is configured for 32-bit mode and the default prescale setting is 256:1, we need to calculate a period value that will enable us to achieve the desired interrupt rate (1s) : 100.10^6 / (256 * Timer Period) = 1Hz
⇨ Timer Period = 100.10^6 / 256 = **390625**



Before moving to Step5, you may want to collapse the **Drivers** tree

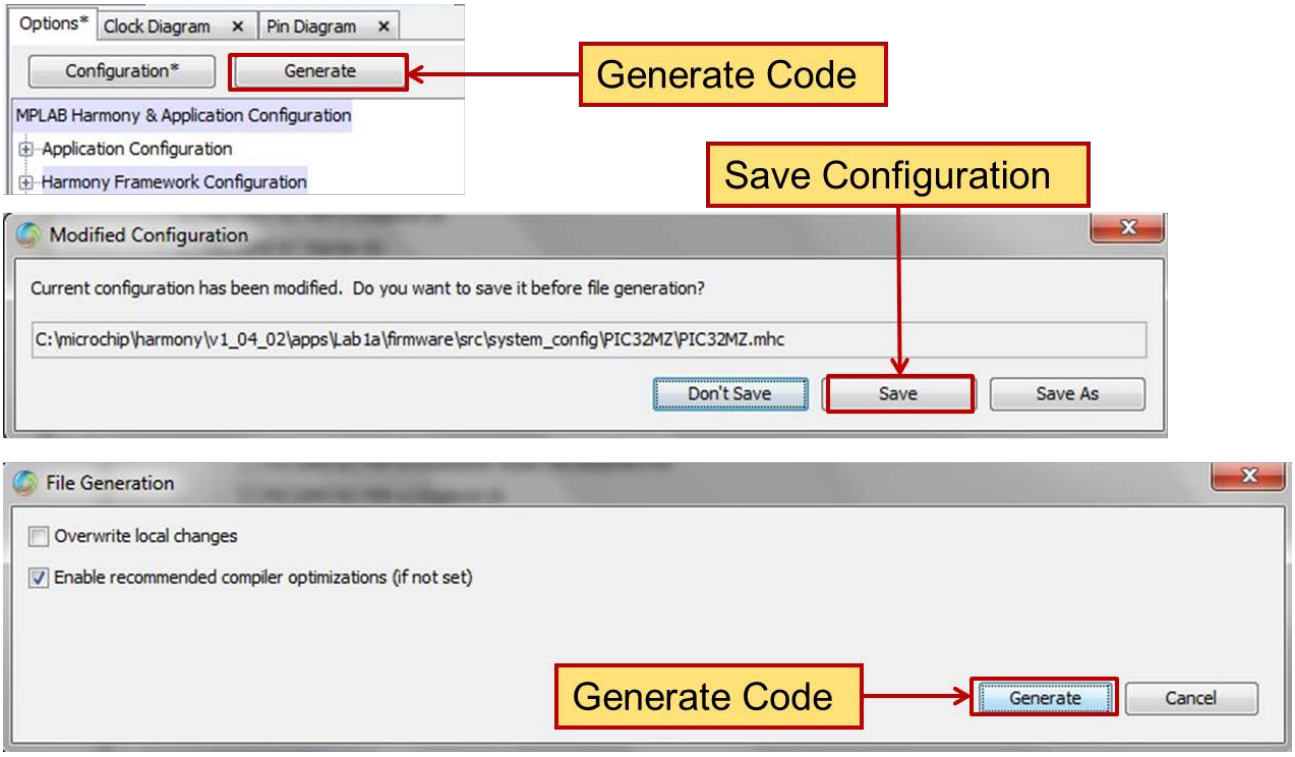
Step 4: Solution

Select and configure Timer Driver as shown



Step 5: Objective – Generate, save and build generated project

At this point, generate and save the configuration as shown below :



Compile the project to verify that the generated project compiles properly without generating errors. Click on 

Note :
At this point, you should be able to debug and step through the application.
Effectively, you have a running MPLAB Harmony system.
However, it is not yet ready to do anything.
Next, you will develop your application state machine logic and make sure the system does what you want it to do. So, you're ready to start implementing the application now.

In Steps 6, 7 and 8 you will:

1. Implement constants of "*enumerated" types.*
    a. Set of named integer constants.
2. Declare, define and access elements of "*struct"* type.
    a. Do you remember structures?
3. Add declarations in the *app.h* file.
4. Add code in the *app.c* and the *system_interrupt.c* files.

C LANGUAGE REFRESHER : enumerated types and structures

Remember this refresher slide on "emum" and "struct" types for future reference in following labs. You may need it. It may come in handy. ☺

```
typedef enum _app_states
{
    APP_STATE_INIT = 0,
    APP_STATE_EVENT,
    APP_STATE_IDLE

} APP_STATES;

typedef struct _app_data
{
    APP_STATES state;
    int        count;
    char       command;

} APP_DATA;

APP_DATA app1Data, app2Data;

app1Data.state = APP_STATE_INIT;
app2Data.state = APP_STATE_INIT;
```

"enum" Types

- Used to give names to constants
- Better than "#define"
  - Groups related names together
  - Associates names with a type
  - Values auto-generated
  - Improves type checking
  - Improves debugging

"struct" Types

- Groups related variables
- Better than separate variables
  - Access member/field with '.'
  - Avoids name collisions

`app1Data.state` different from `app2Data.state`

- Reference struct by one pointer:

```
APP_DATA *pApp = &app1Data;
pApp->state = APP_STATE_IDLE;
```

MPLAB® X IDE EDITOR TIPS

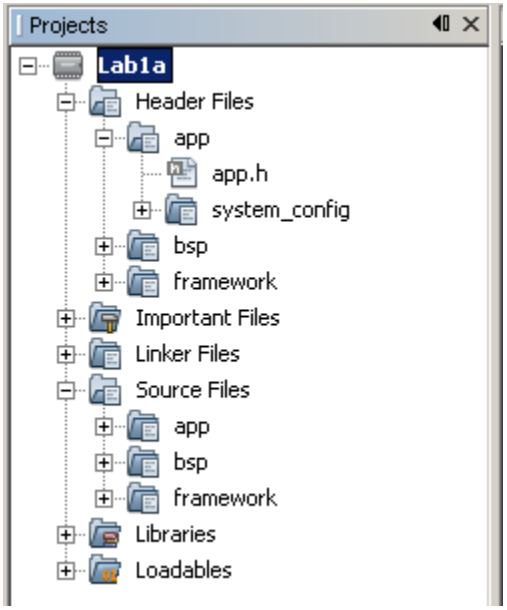
a/ use the **auto-complete** function after typing a few characters : type **CTRL+SPACE**

b/ to navigate labels, functions, structures use hyperlink navigation : **CTRL+"click"**

Step 6: Objective – Add Application States

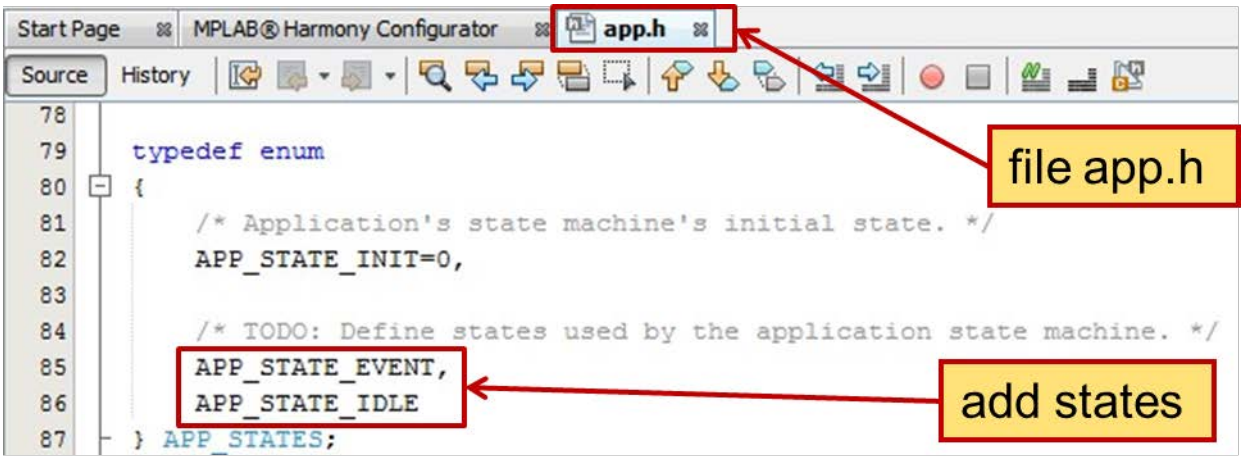
In this step we will add two named constants within an *enum*. These constants are implemented in switch case statements as well as in an interrupt handler to determine the current application state as well as set the next application state for processing.
In short, you are adding states to service in your application.

1. If not already opened or visible, open the Projects window (Window > Projects)
2. If not expanded, expand the Lab1a project tree
3. If not expanded, expand Lab1a header files
4. Open the file app.h: (located under Header Files, in app folder)
    a. In **typedef enum** "APP_STATES", add two constants under
    /* TODO: Define states used by the application state machine. */,:
        i. → APP_STATE_EVENT
        ii. → APP_STATE_IDLE
5. These two "states" will be used in the following Steps 8 and 7 respectively.



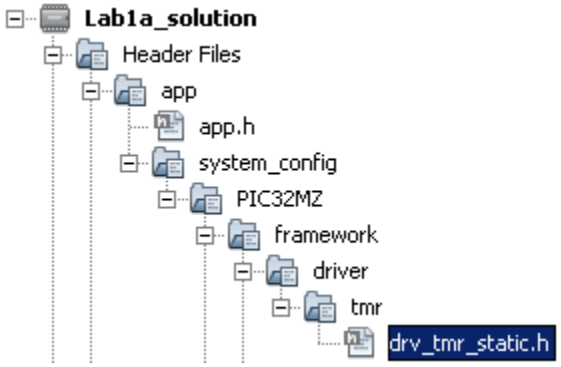
Step 6: Solution

1. Open file app.h
2. Add two named constants (application states) as shown.
3. Save the file, before closing.



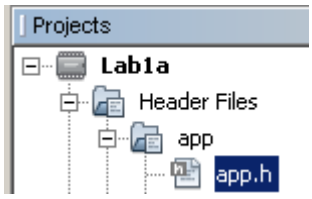
Step 7: Objective – Start Timer Driver and set application states

1. Open file app.c: (located under Source Files in the app folder).
2. In the function ***APP_Tasks(),*** you will add code in three switch case statements:
   - *In the existing case statement:* **APP_STATE_INIT**
     - Add code → to start Timer Driver Service
       Hint: to help you, look in the drv_timer_static.h file for the function prototypes :




```
void DRV_TMR0_Initialize(void);

inline void DRV_TMR0_Start(void);

inline void DRV_TMR0_Stop(void);

inline void DRV_TMR0_CounterClear(void);

void DRV_TMR0_CounterValueSet(uint32_t value);

uint32_t DRV_TMR0_CounterValueGet(void);
```

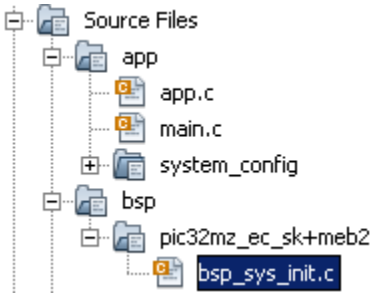
- Add code → Update **appData.state** to IDLE
  Hint : Look in app.h file to find the various appData.state states




```
typedef enum
{
        /* Application's stat
        APP_STATE_INIT=0,

        /* TODO: Define state
        APP_STATE_EVENT,
        APP_STATE_IDLE

} APP_STATES;
```

```
typedef struct
{
    /* The applicatio
    APP_STATES state;

    /* TODO: Define a


} APP_DATA;
```

- Under /* TODO: implement your application state machine.*/, in **case APP_STATE_EVENT** state machine
  - Add code → Toggle LED 3 on PIC32MZ SK
    - Hint: see file bsp_sys_init.c for BSP_LEDToggle(arg) function. You want to toggle LED 3



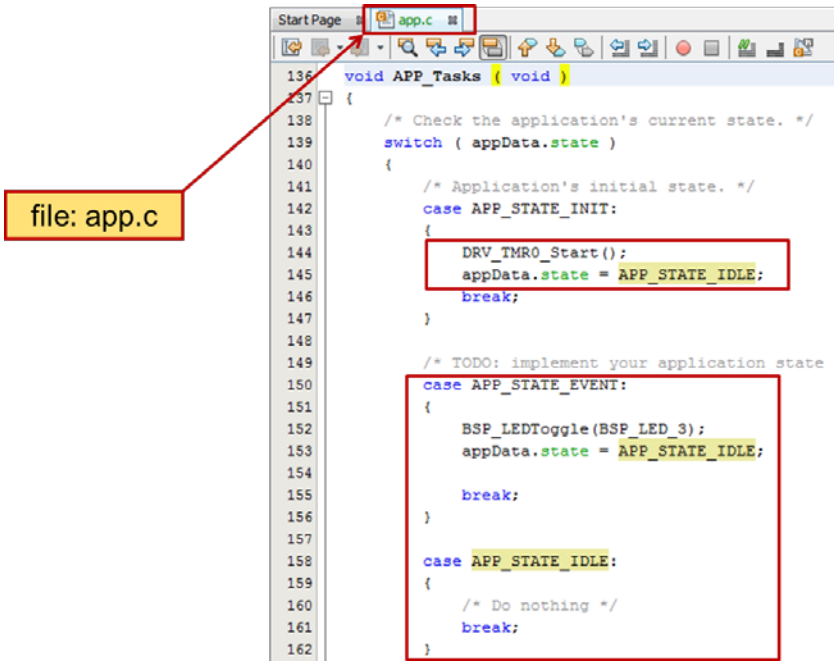

```
void BSP_LEDToggle(BSP_LED led)
{
    PLIB_PORTS_PinToggle(PORTS_ID_0, PORT_CHANNEL_H, led );
}
```

    - Add code to → set appData.state back to IDLE (after toggling the led). Look above for appData.state states. Do not forget to also add a break; at the end of this 2nd case

- *Finally, create a 3rd case statement for the remaining IDLE appData.state →* APP_STATE_IDLE
  - This state does nothing so just add a break; inside

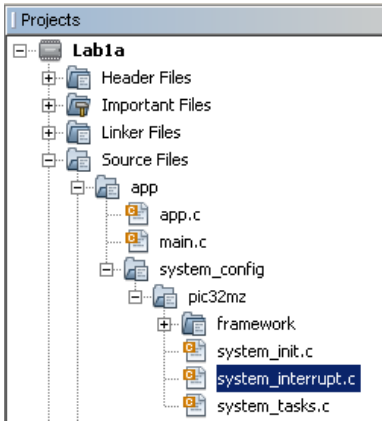
Step 7: Solution

1. In file app.c:
    a. Start Timer Driver service and set application state to IDLE.
    b. Add case statement for EVENT state and add code .
        i. Toggle LED 3 and then set app state to IDLE.
    c. Add case statement for IDLE state. Exit.
    d. Once done, save the file.



Step 8: Objective – Service ISR and update state for next event

1. Open the file system_interrupt.c:



   a. Preceding the ISR Handler, below the header files #include, declare and provide external reference for APP_DATA appData. (The appdata declaration is located in app.c file)
   b. In TIMER3 interrupt function __ISR(*_Timer_3_Vector, …)* **before** the existing function which already clears the TIMER3 interrupt flag
      i. Add code to → Update appData.state to the EVENT state.
      Hint: Access variable as structure member .

      Setting this next state will enable BSP_LedToggle(BSP_LED_3); to be executed in file app.c.

Congratulations! You're done. First do a clean build  and you are now able to **build, program, and run**  the "blinky LED" application and see LED3 on the PIC32MZ EC Starter Kit (or led D4 on the MEB II board) blink briefly, once every second.
You're now a MPLAB® Harmony developer ;=)

The LED blinks at a constant rate (1 Hz) while the main super loop in the system is running. But, if the super loop hangs (or suffers excessive delays) the LED stops blinking (or "skips a beat"). So, the blinky LED" application is a very useful indicator of the health of the system.

Feel free to debug it and step through the code to see how it works. As you continue stepping through the project, you will eventually arrive back at the super loop in the main function. Fundamentally, this is how polled state machines execute within a MPLAB Harmony system

Note: Don't be surprised if you cannot step into the PLIB function calls. They are implemented as inline functions and source code is provided in the MPLAB® Harmony installation. It is possible to rebuild the PLIB, converting them to actual function calls, without optimizations and with debug symbols enabled, so that you can step through them. But, they are generally very simple functions that provide access to peripheral Special Function Registers (SFRs) through an abstracted C-language function call interface that remains the same on all parts on which they are supported.

Time permitting; explore the Lab1a project files and folders. Observe that the project consists of several "logical" folders within the MPLAB® X IDE and several physical folders on disk. This organization is used consistently by MPLAB Harmony applications to keep the files well organized. The MPLAB® X IDE separates header (**`.h`**) files from source (**`.c`**) files, so the logical folder structure duplicates (with some small differences) the physical folder structure on disk under both the **`Header Files`** and **`Source Files`** top-level logical folders. In most cases, the folders on disk correspond directly to the logical folders in the MPLAB® X IDE, but the header files and source files are not separated on disk as they are in the MPLAB X IDE logical folder tree. Also, the **`app`** logical folder corresponds to the **`src`** folder on disk.

The application's **`src`** folder contains the **`main.c`** file as well as the **`app.c`** and **`app.h`** files that implement the application. (**Note:** By convention, the main.c file is identical for all MPLAB® Harmony applications.) The **`system_config`** folder normally holds one or more configuration-specific folders (**`system_config\PIC32MZ`** in this case) that each contains a complete set of configuration files for an MPLAB Harmony application.

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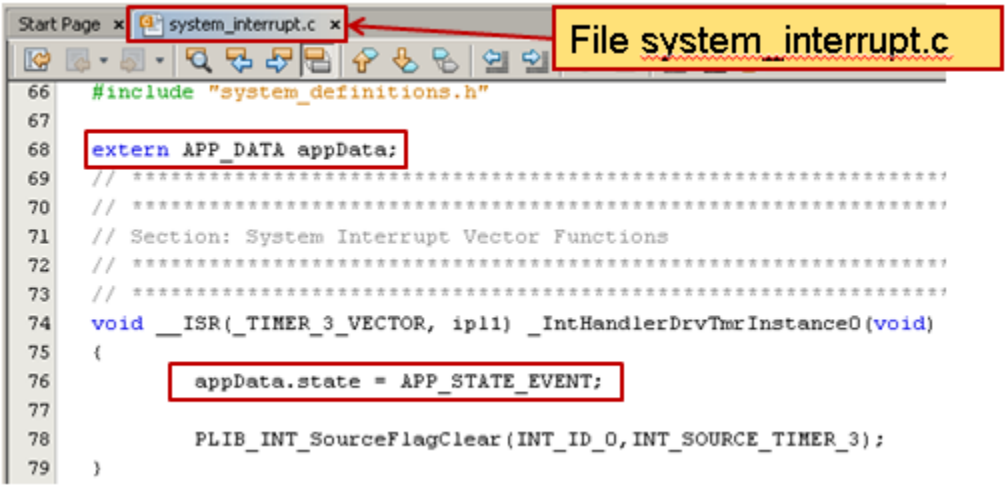
Step 8: Solution

1. In file system_interrupt.c:
    a. Declare external reference for APP_DATA appData.
    b. Update appData.state for next event.



LAB 1b: Adding UART Communication

LAB 1b: Adding UART Communication

Purpose:

After completing Lab 1b, you will have an introduction to the UART Static Driver and continue your learning with the capabilities of the MPLAB® Harmony Configurator.

Overview:

In this lab, you will add a UART to your existing project. The lab result will show a character being transmitted out on the UART TX, every one second, which is the same toggle rate of the LED3 on the PIC32MZ EC Starter Kit. The lab will demonstrate how easy it is to both enable and configure new PIC32 features using MHC.

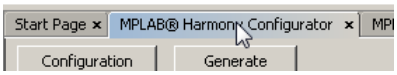
Procedure:

1. First, **close** the Lab1a project and **open** the Lab1**b** project :
   File > Close Project (Lab1a)
   File > Open Project > C:\microchip\harmony\v1_05\apps\Lab1b\firmware\Lab1b.X
2. We must set Lab1b as Main Project to be able to use MHC : **Set as Main Project**
3. We need to enable MHC : **Tools > Embedded > MPLAB Harmony Configurator**
4. For Lab 1b, there are six steps, shown in Part 1 and Part 2. All six steps must be completed before you will be ready to build, download, and run the application.

- **Part 1: With MHC, add UART Functionality**
  - Step 1 – With MHC, add USART Static Driver
  - Step 2 – With Harmony Pin Table feature, connect UART2 to pin 61 to enable UART TX
  - Step 3 – With MHC, Generate Code
  - Step 4 – With MHC, Merge Auto-Generated and custom code
  - Step 5 – Using MHC help, find USART API for sending a byte
- **Part 2: Add Application code**
  - Step 6 – Add code to send USART byte

Each step has a short list of requirements to guide you in the solution development. Following each set of requirements, answers are provided. You can refer to the answers as needed.

Step 1: Objective – Enable and Configure the USART Driver



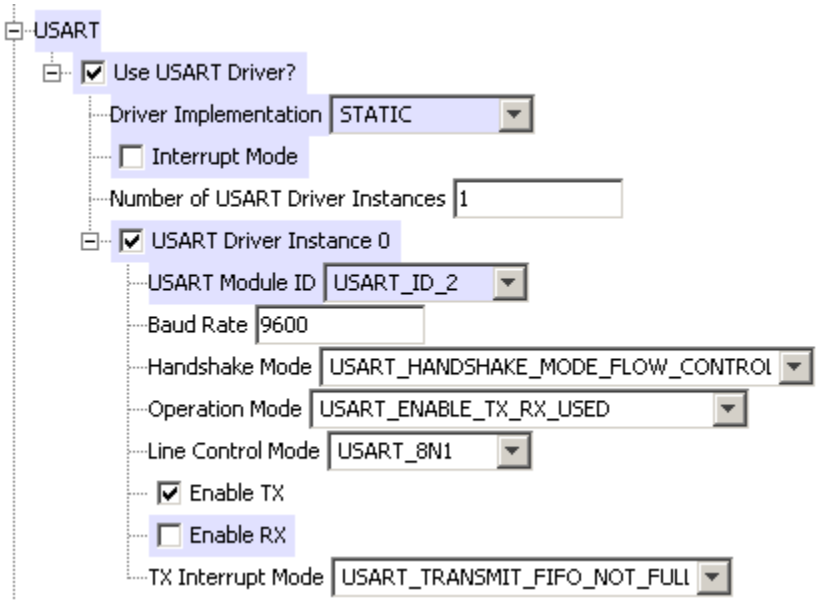
1. Select the **MPLAB® Harmony Configurator** tab
2. Expand the **Harmony Framework Configuration** tree, expand **Drivers**, expand **USART** tree.
    a. Check the **Use USART Driver?** box
    b. Select **Driver Implementation** → STATIC
    c. Make sure that **Interrupt Mode** checkbox is **deselected**.

    d. **Number of USART Instances** → 1 (default)
        i. Select and Expand **USART Driver Instance 0**
        ii. Set **USART Module ID** → USART_ID_2
        iii. Disable USART RX → uncheck **Enable RX**

==========

Step 1: Solution

1. Select and Configure USART TX Driver as shown.
2. Ensure that Interrupt Mode is deselected.
3. Disable USART RX.



Step 2: Objective – Map UART2 TX to the pin 61

1. Using MHC, map UART2 TX to pin 61.

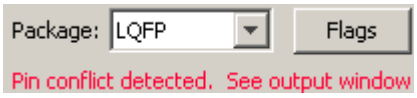
   a. Select **MPLAB® Harmony Pin Diagram** tab.

   b. At the bottom of the window, select the **MPLAB® Harmony Pin Table** tab

   Note : You may have to enlarge the Harmony Pin Table in order to see the UART2 module which is at the very bottom of the window.

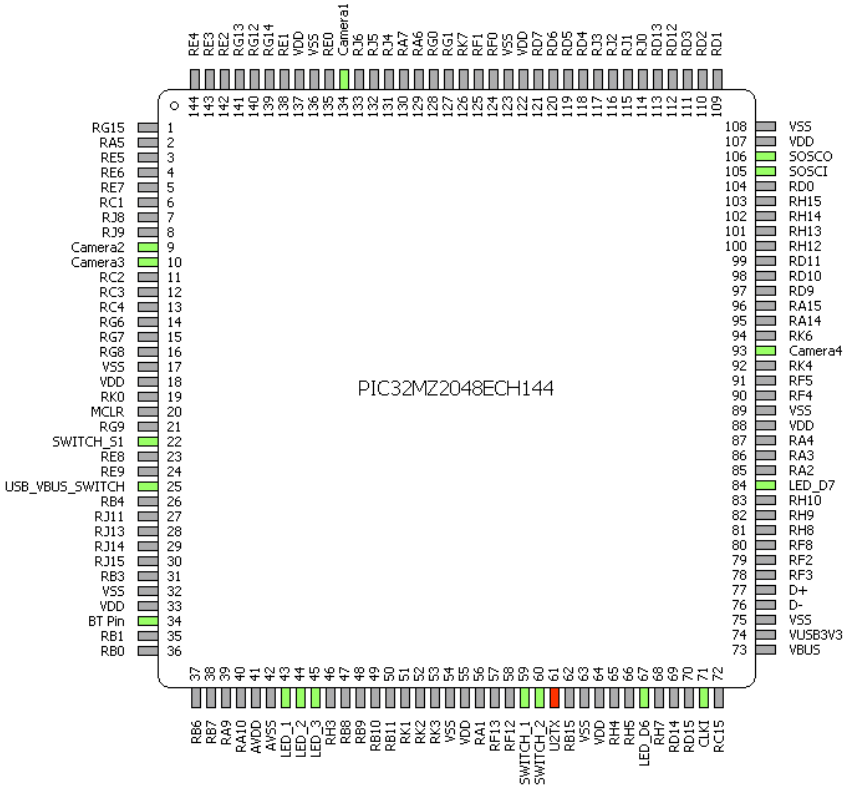
   c. Click the appropriate cell to enable UART 2 “USART_ID_2” on the device **pin 61** column

   IMPORTANT : this pin is shared with a pushbutton SWITCH_3 unused in this Lab, so **do not care** about the **Pin conflict detected** message)



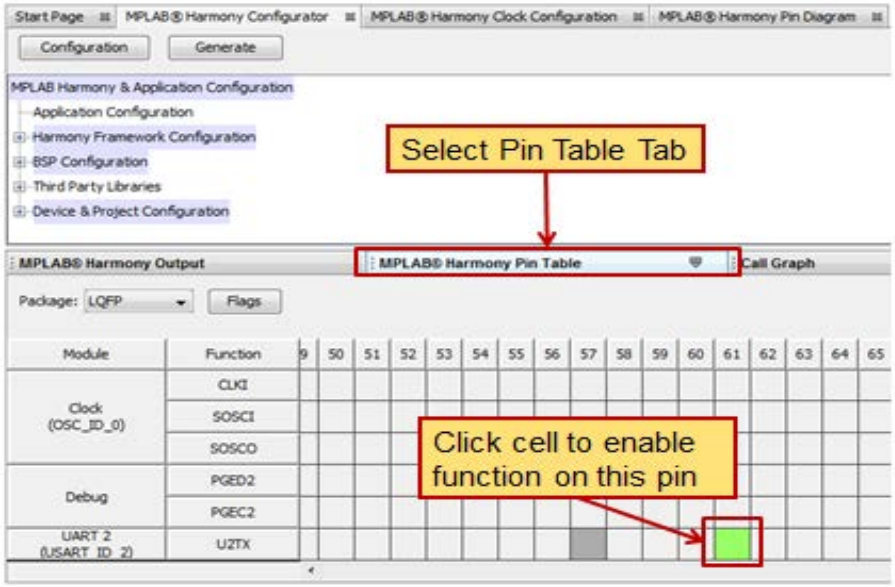
   Note : as you move your mouse away from the cell, it should now be green.

Take a moment and navigate around the tool to see what capabilities it offers.



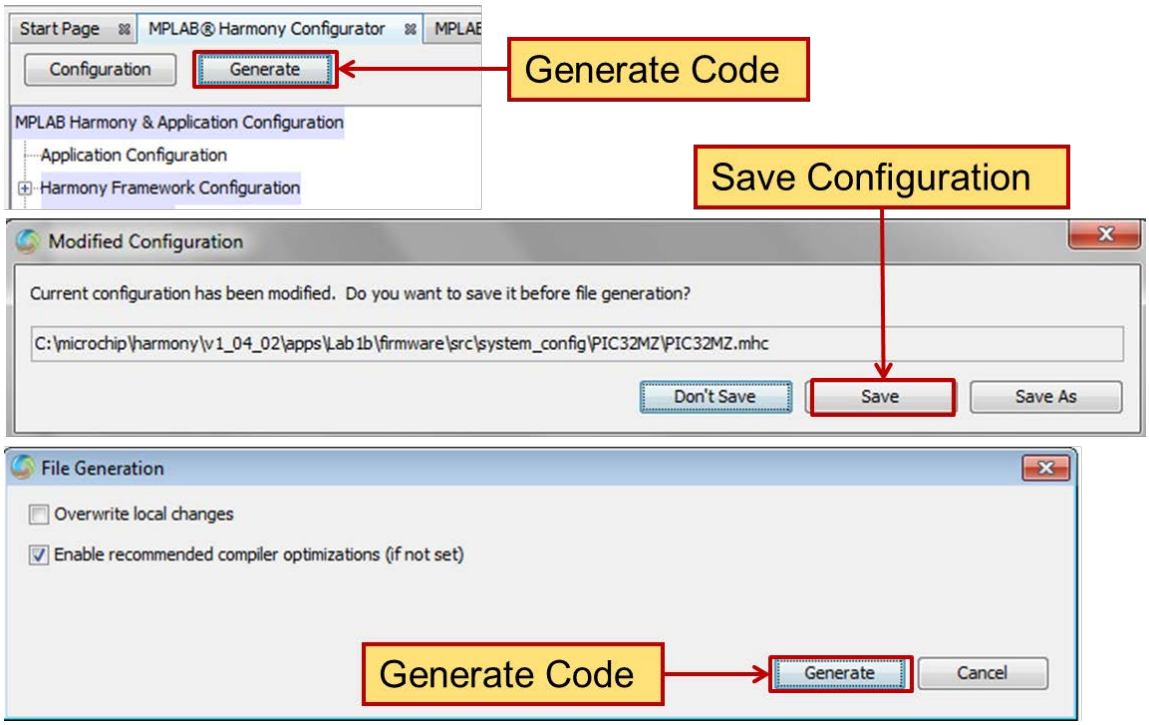
Step 2: Solution

1. Enable UART2 TX on Pin 61.
    a. Select the Pin Table Manager Tab as shown and then scroll to the U2TX field (Y-axis) and then pin 61 (X-Axis) and then click once in the shared cell. You should see the cell turn to green.



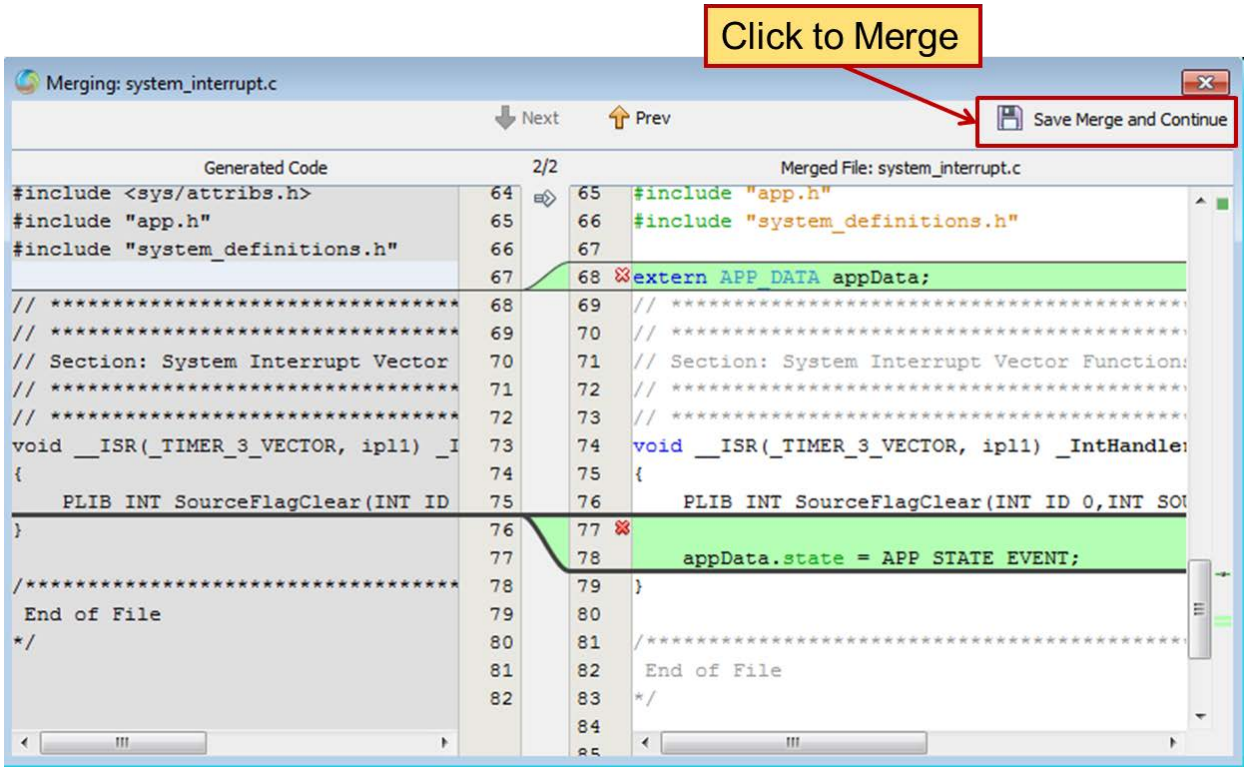
Step 3: At this point generate and save the configuration as shown

First, select the **MPLAB® Harmony Configurator** tab and follow instructions :



Step 4: Merge Auto-Generated and custom code

The "DIF" window opens up and shows the differences between auto-generated code and the manual modifications we just made in previous steps.



This tool is a great way to check and accept the code changes you just made against the previous source. We have added the USART functionality to the existing running MPLAB Harmony system.

Build the project to make sure there is no error at this step. Push the icon 

Now, you're ready to start implementing the application code.

Step 5: Objective – Locate the UART APIs in documentation

1. Within MHC, locate and familiarize yourself with USART API for sending a byte.

   Select the **MPLAB® Harmony Configurator** tab
2. Expand the **Harmony Project Configuration** tree to see the USART :
   i. Right click on **Use the USART Driver**. USART Driver Library help topic will appear on right pane.
   ii. Next, find the **Library Interface** link and click on it to see the APIs
   iii. Look at the **DRV_USART_WriteByte** API.

Note: The Library Help syntax reflects a USART Dynamic Driver. The Static USART API is effectively the same as with Dynamic. See the Framework Help note below for the suitable change in the Dynamic API to accommodate the Static Driver.

Framework Help

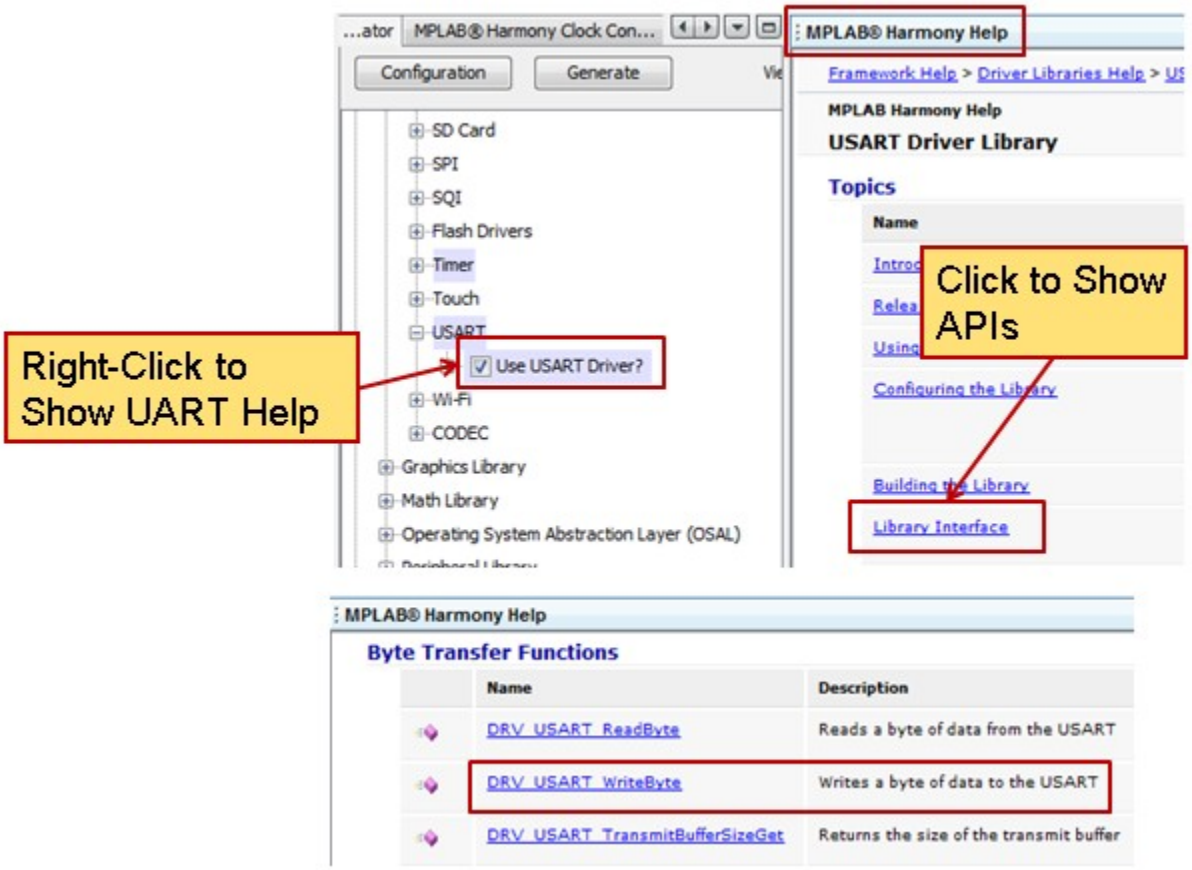
MPLAB Harmony supports Static implementation through MHC for applications with smaller memory requirements. The Static implementation is configuration-specific and differs from Dynamic implementation in the following ways:

- Code is generated by MHC based on the configuration provided by the user
- Generated code is placed under the application directory within the specific configuration
- Some parameters for APIs may be omitted in Static implementation versus Dynamic implementation
- For multi-instance support, APIs are modified with the instance number:
  - *Dynamic:* DRV_SPI_Initialize
  - *Static:* DRV_SPI0_Initialize

Refer to the Library Interface section for the specific module or library for information on which APIs support Dynamic and/or Static implementation.

Step 5: Solution

1. Find and familiarize yourself with USART API for sending byte. We will use this API in step 6.



Step 6: Objective – Write byte to UART

1. Under Source Files > app subfolder, open the file app.c:
    a. In function ***APP_Tasks(),*** we need to add code in one switch case statement to Transmit one byte over the UART :
        i. **case APP_STATE_EVENT:**
            1. Add code to → Send byte character 'a' as function argument.
                a. Hint: You just looked up the API for this function.
                b. Remember you're using USART Driver Instance 0 (static) .

Congratulations! You're almost there. Before proceeding just two more quick items:

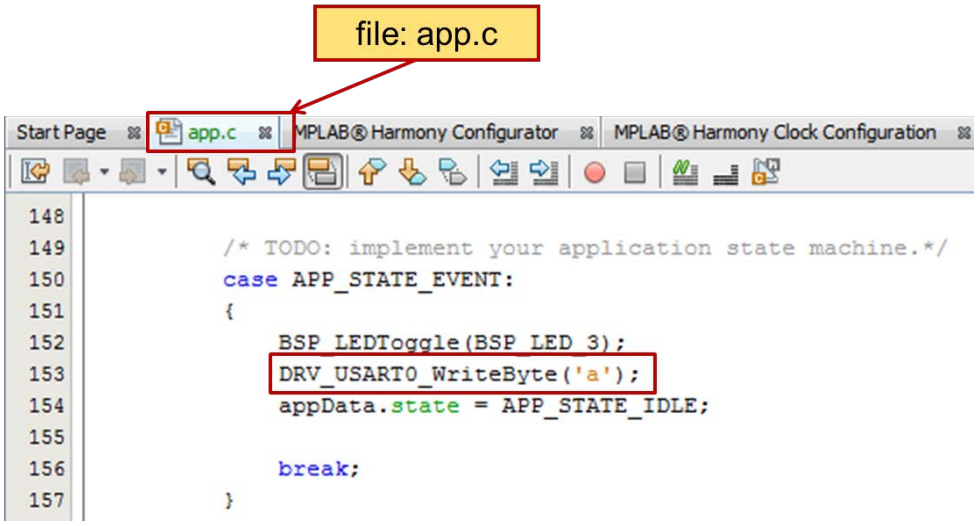
1. Ensure the UART-to-USB adaptor is connected to the **J2 header** on the **MEB II**.
2. Connect a USB cable to the PC and launch **Tera Term Pro** or any other terminal emulator with these settings: **9600 baud, 8, N, 1. (Setup > Serial port > …)**

First do a clean build  and you are now able to **build, program, run**  and see LED D4 blink on MEB II once every second, and also see the character 'a' show up on the terminal each and every second.

==========

Step 6 : Solution

1. Write a byte (character 'a') for each and every event.



LAB 2a: Adding Graphics Library

LAB 2a: Adding Graphics Library

Purpose:

After completing Lab 2a, you will have an understanding of how to use MHC to add and enable graphics into your application. We will keep the graphics simple and basic for this lab. You can build on this foundational knowledge at a later time.

Overview:

In this lab, you will start with your previous project after you completed Lab 1b.
Using MHC, you will select and enable a Graphics Library application and integrate it into Lab 1b.

Procedure:

- First, **close** the Lab1b project and **open** the Lab2**a** project :

File > Close Project (Lab1b)
File > Open Project > C:\microchip\harmony\v1_05\apps\Lab2a\firmware\Lab2a.X

- We must set Lab2a as Main Project to be able to use MHC : **Set as Main Project**
- We need to enable MHC : **Tools > Embedded > MPLAB Harmony Configurator**
- For Lab 2a, there are six steps, as follows. All six steps must be completed before you will be ready to build, download and run the application.

- **With MHC, add Graphics Functionality**
  - Step 1 – Add pre-built GRC generated files to the project
  - Step 2 – With MHC, enable Graphics into your project
  - Step 3 – With MHC, Generate Code
  - Step 4 – With MHC, Merge Auto-Generated and custom code
  - Step 5 – Add code: Initialize screen, draw box, and add text
  - Step 6 – Add code: Toggle rectangle, fill color as LED changes

Each step has a short list of requirements to guide you in the solution development. Following each set of requirements, answers are provided. You can refer to the answers as needed.

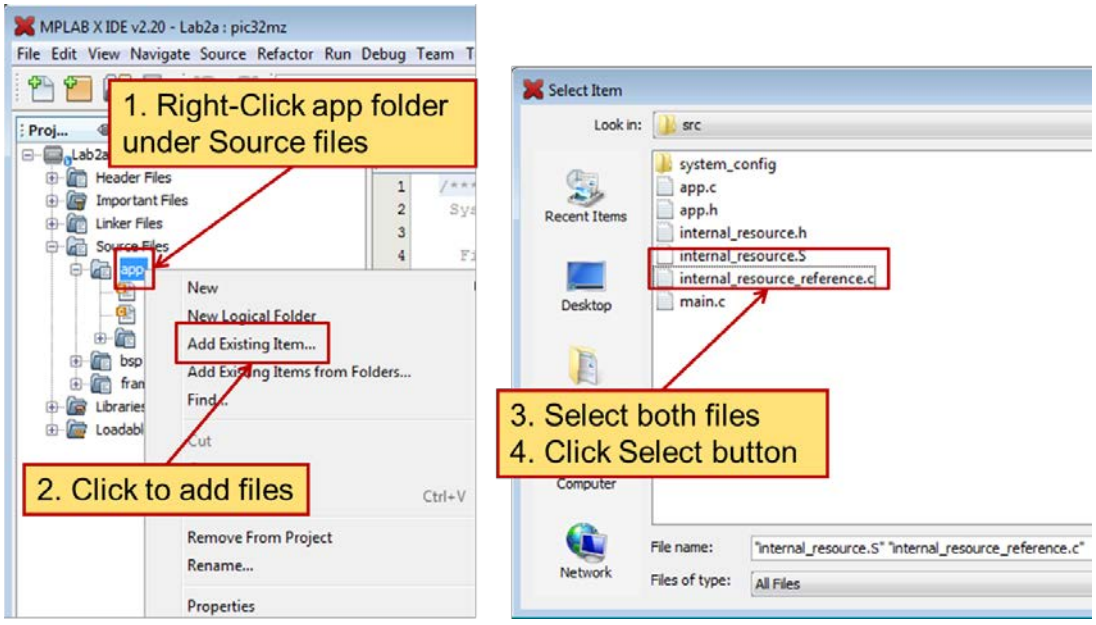
Step 1: Add GRC generated files to the project library

1. Close **Lab1b** project and open **Lab2a** project
2. Set **Lab2a** project as main project
3. We need to add 2 files to the project in the **app** folder under source files :

Right click the **app** folder and select **Add Existing Item**

a. internal_resource.S
b. internal_resource_reference.c

Note: These two files, along with the internal_resource.h file have been provided for you in the following folder : **C:\microchip\harmony\v1_05\apps\lab2a\firmware\src**

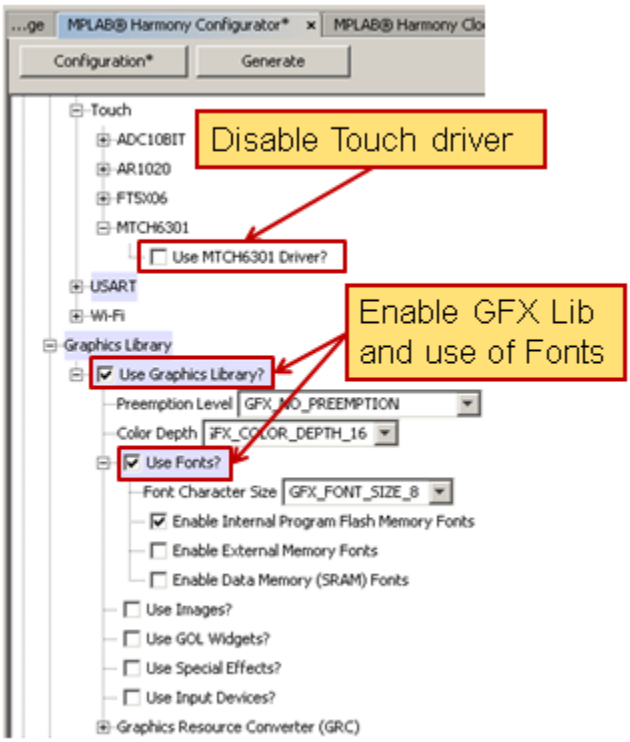


Note: Graphics Resource Converter (GRC)

a. For this exercise, these two graphics resource files with fonts are provided to save time.
b. From Harmony v1.04 GDDX functionality is also present in Harmony Configurator. Future versions of this class will show how to create graphics using MHGC (MPLAB Harmony Graphics Composer).

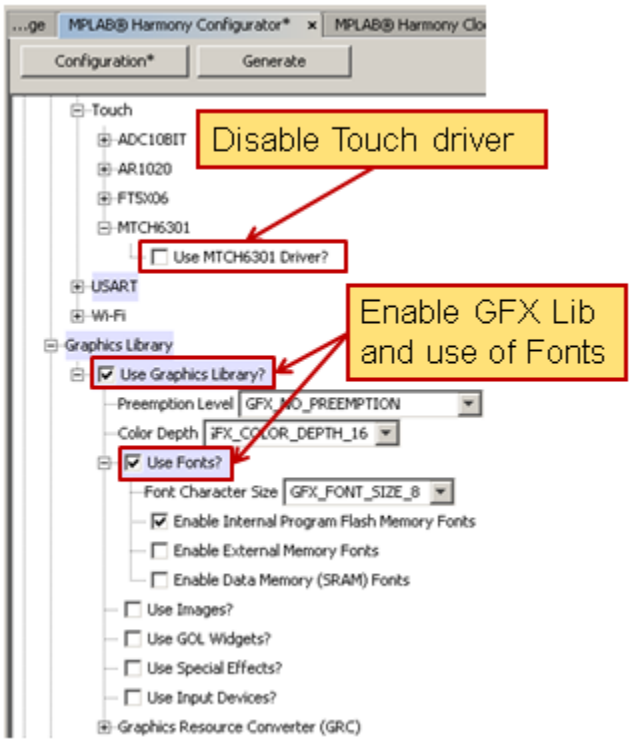
Step 2: Objective – Configure the Graphics Library

1. Launch MHC : **Tools > Embedded > MPLAB® Harmony Configurator**
2. Using MHC, configure the Graphics Library :
    a. In the MPLAB Harmony Project Configuration tree, expand the **Harmony Framework Configuration** tree
    b. Expand the **Graphics Library** tree
        i. Enable Graphics Library : check the **Use Graphics Library** box
        ii. Enable Fonts : check the **Use Fonts** checkbox
3. With MHC, under Drivers, locate Touch Driver.
    a. Expand the **Drivers** tree
        i. Expand the **Touch** tree
            1. Locate and expand **MTCH6301** tree
            2. **Ensure** that the **Use MTCH6301 Driver** box is **disabled**

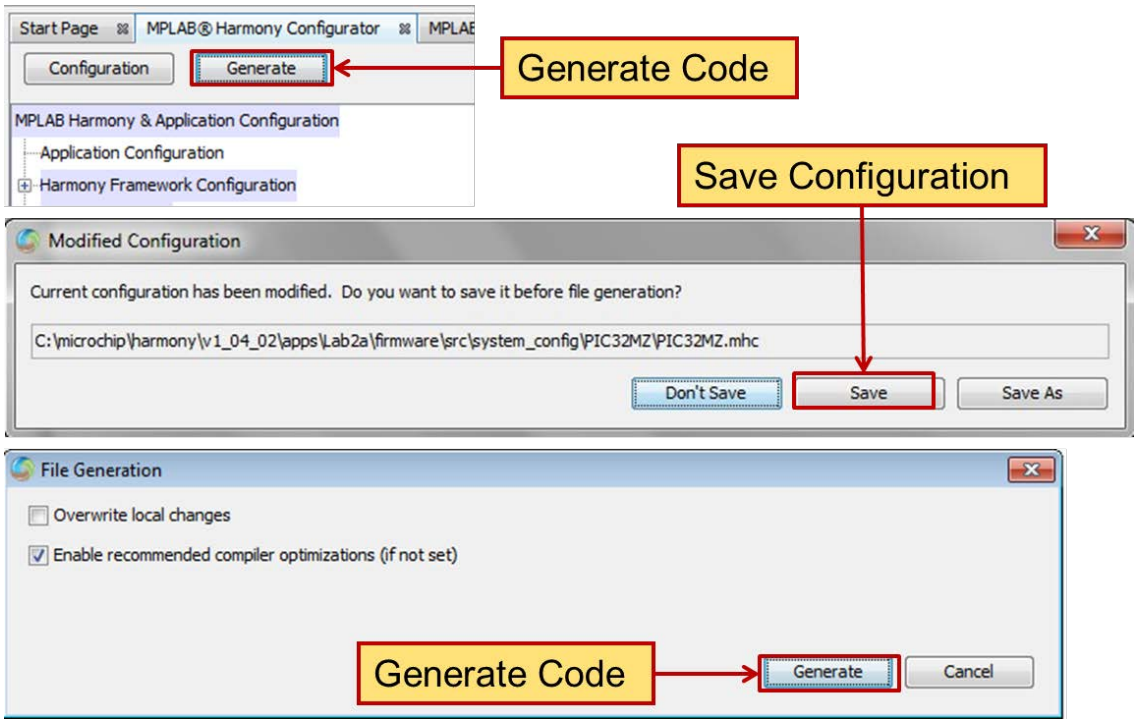


Step 2: Solution

1. Using MHC, configure the Graphics Library.

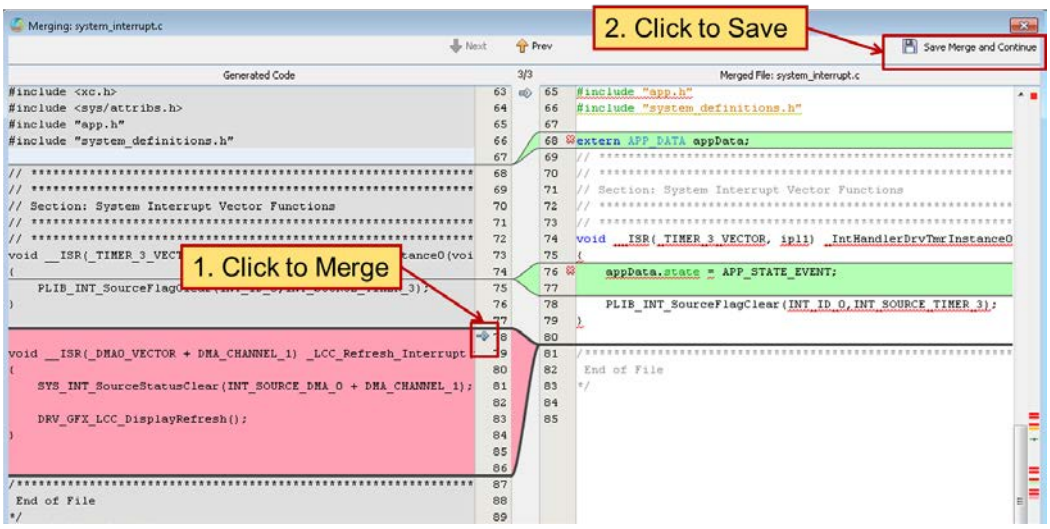


Step 3: At this point generate and save the configuration as shown:

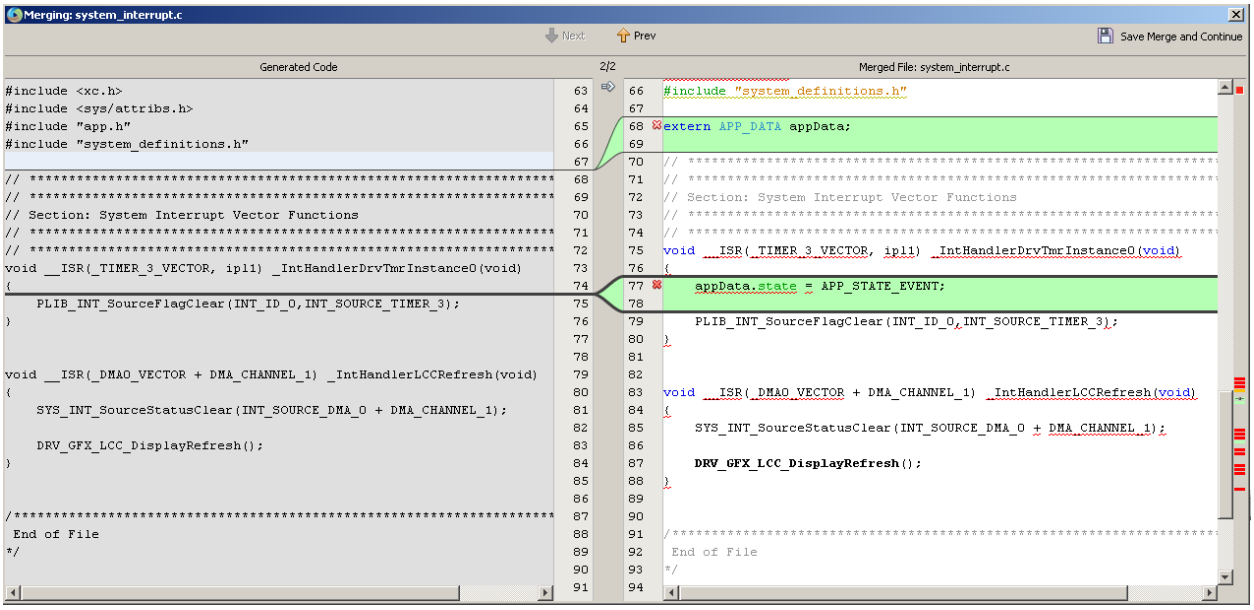


Step 4: Merge Auto-Generated and custom code

a. Click on the right arrow on the right of the pink code block to **Merge** left code block into right code. Look at the 2nd screenshot below to see the result of the Merge BEFORE to click **Save Merge and Continue**
b. Click on **Save Merge and Continue**



Window after **Click to Merge** and BEFORE click to save :



This tool is a great way to check and accept the code changes you just made against the existing source.
Compile the project to verify that the generated project compiles properly without generating errors.

Step 5: Objectives – Initialize the screen, draw a box and display text

First you need to add #include "internal_resource.h" file at the beginning of app.c file.

In this step you will update one switch case statements in file app.c.

For all GFX Library API help, refer to the integrated GFX Library Help window, starting at the Library Interface top level help section.

To perform this step you can either look for the functions and their parameters in the documentation or copy/paste the necessary code from following pages.

Open file app.c, in app folder, locate case statement APP_STATE_INIT and add code :

1. Wait for GFX Library to initialize→ GFX_Status(argument);
   i. This function provides the current status of the GFX Module.
   ii. See System and Client Interfaces (Help window)

Before executing the code within the APP_STATE_INIT case, we need to wait for GFX Library to initialize but we don't want to BLOCK the appData.state state machine until it gets initialized : use GFX_Status(argument) function. The argument is the object index which was returned by GFX_Initialize (use MPLAB X search to find it).

2. Set screen color→ GFX_ColorSet(arg1, arg2);
   After the existing DRV_TMR0_Start(); function add GFX_ColorSet(arg1, arg2);
   i. This function sets the color to be used to render primitive shapes & text. Color to use is GREEN (argument2). see **Note1 below**
   ii. Graphics Primitive Layer > Graphics Primitive Layer API > Color Functions (Help window)

   iii. Clear the screen→ GFX_ScreenClear(argument);Graphics Primitive Layer > Graphics Primitive Layer API > Initialize Functions (Help window)

   This function clears the screen with current color and sets cursor position to (0, 0).

3. Set screen color→ GFX_ColorSet(arg1, arg2);
   i. Color to use is WHITE (argument2). (*) see **Note1 below**
   ii. Graphics Primitive Layer > Graphics Primitive Layer API > Color Functions (Help window)

4. Draw rectangle w/white box→ GFX_RectangleDraw(arg1, arg2, arg3, arg4,arg5);
   i. This function renders a rectangular shape using the given left, top, right and bottom parameters to define the shape dimension. Use 40,20,60,80 for arg2 to arg5.
   ii. Graphics Primitive Layer > Graphics Primitive Layer API > Polygon Rendering Functions help

5. Set Display Font→ GFX_FontSet(arg1,arg2);
   i. This function sets the current font used to render strings and characters
   ii. See Graphics Primitive Layer API →Text Rendering Functions (Help window)

For arg2, we need to provide a pointer to the Font which will be used : &My_Font

6. Display “D4” name under box→ GFX_TextStringDraw(arg1, arg2, arg3, arg4,arg5);
   i. This function renders the given string of character using the currently set font, and color to the location defined by the given x, y position. Use 40, 90 for the x, y positions. As we want to display “D4” under the box just drawn previously
   ii. See Graphics Primitive Layer API →Text Rendering Functions (help window)

==========

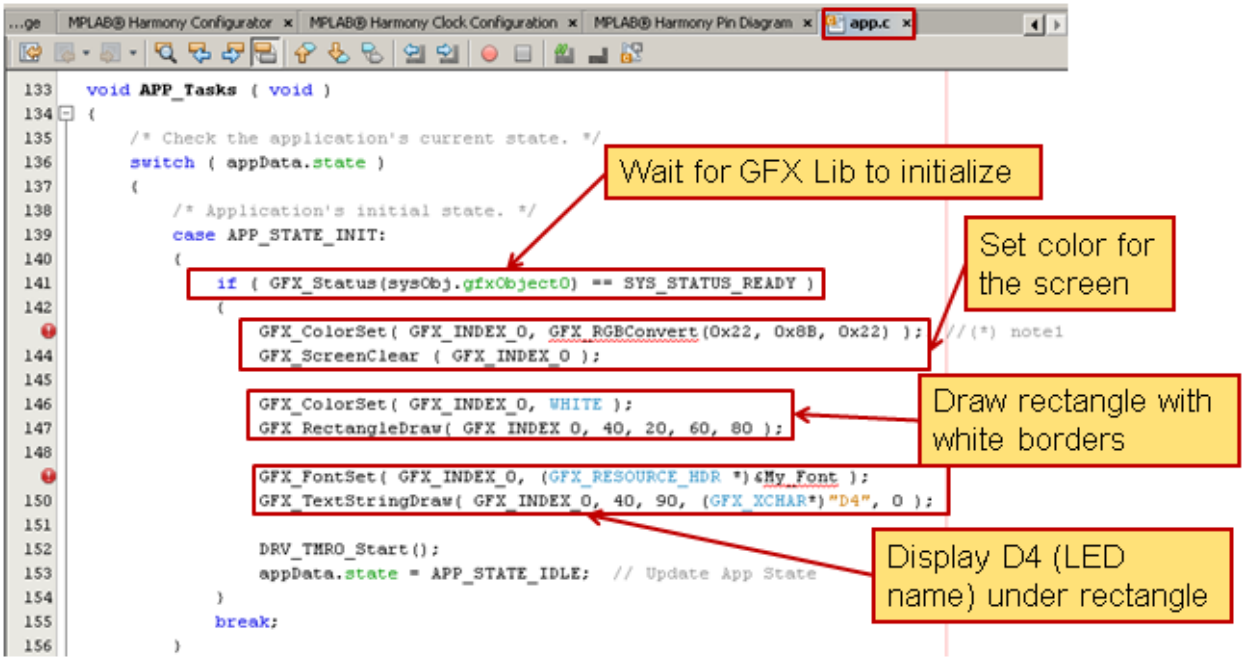
Step 5: Solution

For reference, here is the solution code which you can copy and paste into your solution. (file: **app.c**). You will also be provided the solution lab.

```
void APP_Tasks ( void )
{
    /* Check the application's current state. */
    switch ( appData.state )
    {
        /* Application's initial state. */
        /*  Step 5 solution.  */
        case APP_STATE_INIT:
        {
            if ( GFX_Status(sysObj.gfxObject0) == SYS_STATUS_READY )
            {
                GFX_ColorSet( GFX_INDEX_0, GFX_RGBConvert(0x22, 0x8B, 0x22) );          //(*) note1
                GFX_ScreenClear ( GFX_INDEX_0 );

                GFX_ColorSet( GFX_INDEX_0, WHITE );
                GFX_RectangleDraw( GFX_INDEX_0, 40, 20, 60, 80 );

                GFX_FontSet( GFX_INDEX_0, (GFX_RESOURCE_HDR *)&My_Font );
                GFX_TextStringDraw( GFX_INDEX_0, 40, 90, (GFX_XCHAR*)"D4", 0 );

                DRV_TMR0_Start();
                appData.state = APP_STATE_IDLE;  // Update App State
            }
            break;
        }

        /* TODO: implement your application state machine.*/
        /*   We will work this state in Step 6   */
        case APP_STATE_EVENT:
        {
            break;
        }
        /* The default state should never be executed. */
        default:
        {
            /* TODO: Handle error in application's state machine. */
            break;
        }
    }
}
```

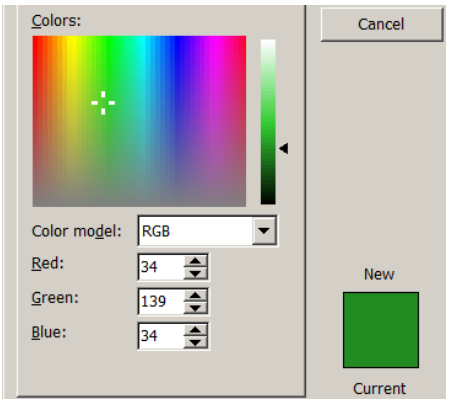
Test for active GFX Module (Library has been initialized for you).

1. Set color and clear screen.
2. Set color and draw rectangle with white border.
3. Set Font
4. Display string “D4” (LED name) under the rectangle.




```
133  void APP_Tasks ( void )
134  {
135      /* Check the application's current state. */
136      switch ( appData.state )
137      {
138          /* Application's initial state. */
139          case APP_STATE_INIT:
140          {
141              if ( GFX_Status(sysObj.gfxObject0) == SYS_STATUS_READY )
142              {
                     GFX_ColorSet( GFX_INDEX_0, GFX_RGBConvert(0x22, 0x8B, 0x22) );///(*) note1
144                  GFX_ScreenClear ( GFX_INDEX_0 );
145
146                  GFX_ColorSet( GFX_INDEX_0, WHITE );
147                  GFX_RectangleDraw( GFX_INDEX_0, 40, 20, 60, 80 );
148
150                  GFX_FontSet( GFX_INDEX_0, (GFX_RESOURCE_HDR *)&My_Font );
151                  GFX_TextStringDraw( GFX_INDEX_0, 40, 90, (GFX_XCHAR*)"D4", 0 );
152
153                  DRV_TMR0_Start();
154                  appData.state = APP_STATE_IDLE;  // Update App State
155              }
156              break;
```

Note1: As a reference only, the GFX_RGBConvert function parameters 0x22, 0x8B, 0x22 correspond to the fields shown in the following figure. The resultant screen color is Green (below screenshot extracted from Word: Font color > More colors



Additional information on the GFX_RGBConvert function

GFX_RGBConvert Macro
Syntax:

- **#define GFX_RGBConvert**(red, green, blue) (GFX_COLOR) (((GFX_COLOR)(red) & 0xE0) | (((GFX_COLOR)(green) & 0xE0) >> 3) | (((GFX_COLOR)(blue)) >> 6))

Description:

- RGB Conversion macro. 24 BPP color to x BPP color conversion. Color depths of 1, 2 or 4 are usually for monochrome/grayscale format. These are not supported in RGB conversion.

COLOR_DEPTH	Conversion
8	8-8-8 to 3-3-2 conversion
16	8-8-8 to 5-6-5 conversion
24	8-8-8 to 8-8-8 conversion or no conversion

Preconditions - None.

Parameters	Description
red	red component of the color.
green	green component of the color.
blue	blue component of the color.

Returns - The converted color data. Size is dependent on the COLOR_DEPTH.

Step 6: Objectives – Toggle rectangle, fill color as LED toggles

In this step you will update one switch case statements in the app.c file.
As with Step 3, refer to the integrated GFX Library Help window, starting at the Library Interface top level help section.
To perform this step you can either look for the functions and their parameters in the documentation or copy/paste the necessary code from following pages.

Open file app.c, and locate case statement APP_STATE_EVENT :
After the line DRV_USART0_WriteByte('a'); add if-else code to:

1. **If** BSP LED state is true, then Test BSP LED State → BSP_LEDStateGet(arg1);
   i. This function returns the present state of the LED. Hint: we are talking about BSP_LED_3.
   ii. See Board Support Package Help → Library Interface → LED Control Functions → BSP_LEDStateGet Function.

2. Set screen color→ GFX_ColorSet(arg1, arg2);
   i. This function sets the color to be used to render primitive shapes & text. Color to use is BRIGHTRED
   ii. See Graphics Primitive Layer API → Color Functions

3. Draw Filled Rectangle→ GFX_RectangleFillDraw(arg1, arg2, arg3, arg4,arg5);
   i. This function renders a filled rectangular shape with the currently set fill style (see GFX_FILL_STYLE) with the given left, top, right, and bottom parameters to define the shape dimension. Use parameters 41, 21, 59, 79, respectively. These coordinates reflect the “inside” of the rectangle drawn in Step 5.
   ii. See Graphics Primitive Layer API → Polygon Fill Rendering Functions

4. **Else** test is false ….. (as in LED is not on)

5. Set screen color→ GFX_ColorSet(arg1, arg2);
   i. This function sets the color to be used to render primitive shapes & text.
   ii. See Graphics Primitive Layer API → Color Functions

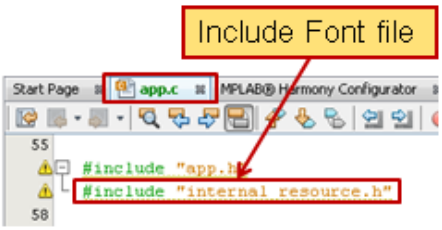
6. Draw Filled Rectangle→ GFX_RectangleFillDraw(arg1, arg2, arg3, arg4,arg5);
   i. This function renders a filled rectangular shape with the currently set fill style (see GFX_FILL_STYLE) with the given left, top, right, and bottom parameters to define the shape dimension. Use parameters 41, 21, 59, 79, respectively. These coordinates reflect the “inside” of the rectangle drawn in Step 5.
   ii. See Graphics Primitive Layer API → Polygon Fill Rendering Functions

For reference, here is the answer code (file: app.c). The solution of this lab is provided in the lab2a_solution project where you can copy paste from the solution app.c file

```
/*   Step 6  solution.  */
case APP_STATE_EVENT:
{
    BSP_LEDToggle( BSP_LED_3 );
    DRV_USART0_WriteByte( 'a' );

    if ( BSP_LEDStateGet(BSP_LED_3) == BSP_LED_STATE_ON )
    {
        GFX_ColorSet( GFX_INDEX_0, BRIGHTRED );
        GFX_RectangleFillDraw( GFX_INDEX_0, 41, 21, 59, 79 );
    }
    else
    {
        GFX_ColorSet( GFX_INDEX_0, GFX_RGBConvert(0x22, 0x8B, 0x22) );
        GFX_RectangleFillDraw( GFX_INDEX_0, 41, 21, 59, 79 );
    }
    appData.state = APP_STATE_IDLE;
    break;
}
/* The default state should never be executed. */
default:
{
    /* TODO: Handle error in application's state machine. */
    break;
}
```

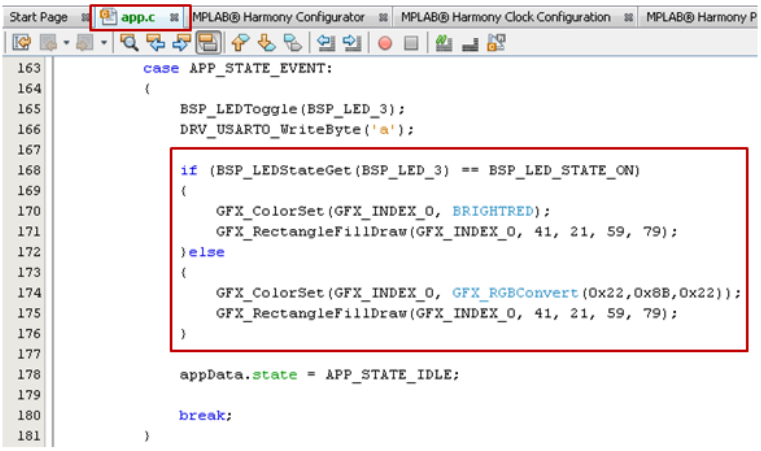
Step 6: Solution

1. First, #include internal_resource.h in the file app.c

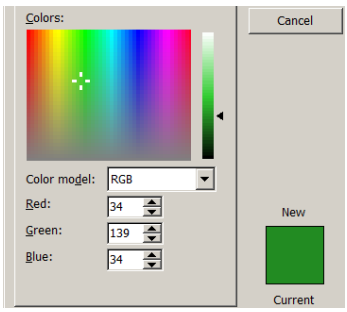


This file is located in folder:
(C:\microchip\harmony\v1_05\apps\lab2a\firmware\src)

2. Next, test whether LED3 is ON. If True, then:
   a. Set color to BRIGHTRED.
   b. Draw Filled rectangle within white box.
3. Else, false:
   a. Set color using GFX_RGBConvert function,
   b. Draw Filled rectangle within white box,



Note: As a reference only, the GFX_RGBConvert function parameters 0x22,0x8B, 0x22 correspond to the fields shown in below screenshot.The resultant screen color is Green.



First do a clean build  and you are now able to **build, program, run**  and see LED D4 blink on MEB II once every second, a screen widget named D4 blink at the same speed as LED D4 toggle rate and also see the character 'a' show up on the terminal each and every second.

LAB 2b: Multi-stack – Creating Complex MPLAB® Harmony Projects

LAB 2b: Multi-Stack - Creating Complex MPLAB® Harmony Projects

Purpose:

After completing Lab 2b, you will have gained additional experience using MHC to add, enable, and configure PIC32 Harmony USB Host MSD and File System Library components.

Procedure:

- In Lab 2b, you will add Harmony USB Host MSD and File System components to the previous project. When the final application is running and you insert a USB Pen Drive into the PIC32MZ EC Starter Kit, a stored message is read from the Pen Drive and displayed on the MEB II glass and also transmitted on UART TX.
- In this lab you will become familiar with several USB Host MSD and File System APIs and how to bring these elements into a system with MHC.
- Also, you will understand how to create a second application configuration and how to process the application states within the overall application.
- There are 12 steps in Lab 2b. **All 12 steps must be completed before you will be ready to build, download, and run the application**.
  Here are the steps you will work through:

  - **Adding USB Host MSD and File Systems Components**
    - Step 1 – Enable USB Host with MSD
    - Step 2 – With MHC, Generate Code, Merge Auto-Generated and custom code
    - Step 3 – With MHC Reconfigure Timer Services
    - Step 4 – With MHC, Generate Code, Merge Auto-Generated and custom code
    - Step 5 – With MHC, create two Application Configurations
    - Step 6 – With MHC, Generate Code, Merge Auto-Generated and custom code
    - Step 7 – Add USB and MSD callback functions
    - Step 8 – Start Timer Service as 1 second event
    - Step 9 – Use Timer Service as 1 second event
    - Step 10 – Add USB MSD application states
    - Step 11 – Add USB MSD application state execution code
    - Step 12 – Update Initialization code in app.c

Each step has a short list of actions to guide you in the solution development. Following each set of requirements, answers are provided. You can refer to the answers as needed

Ensure that the USB debugger cable is attached and the correct hardware and language tools are selected.

All three of these “applications” (Graphics, USB Host MSD and File System Libraries) are running, effectively independently within the MPLAB Harmony system with no conflicts.

PROCEDURE

1. First, **close** the Lab2**a** project and **open** the Lab2**b** project :

File > Close Project (Lab2a)

File > Open Project > C:\microchip\harmony\v1_05\apps\Lab2b\firmware\Lab2b.X

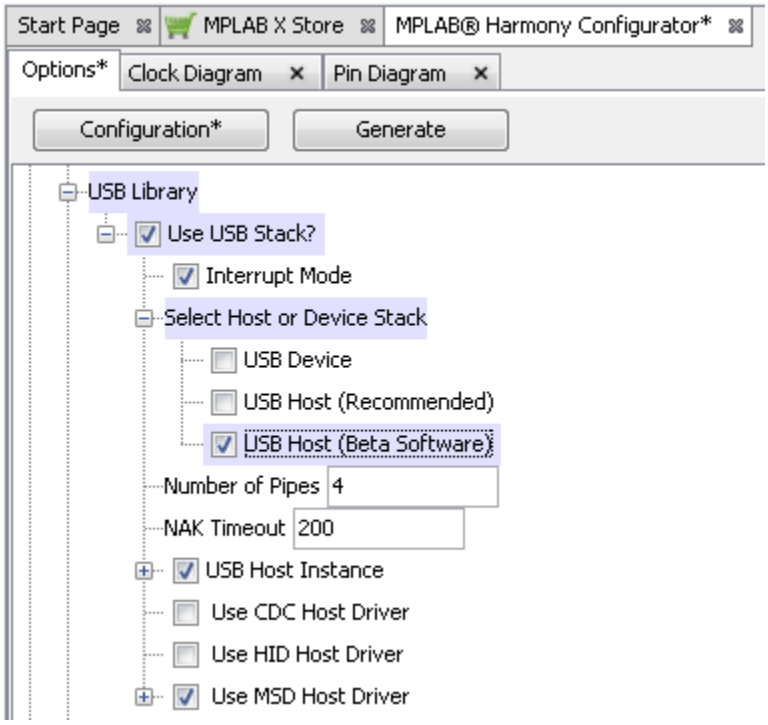
- We must set Lab2b as Main Project to be able to use MHC : **Set as Main Project**
- We need to enable MHC : **Tools > Embedded > MPLAB Harmony Configurator**

Step 1: Objective – Enable USB Host with MSD

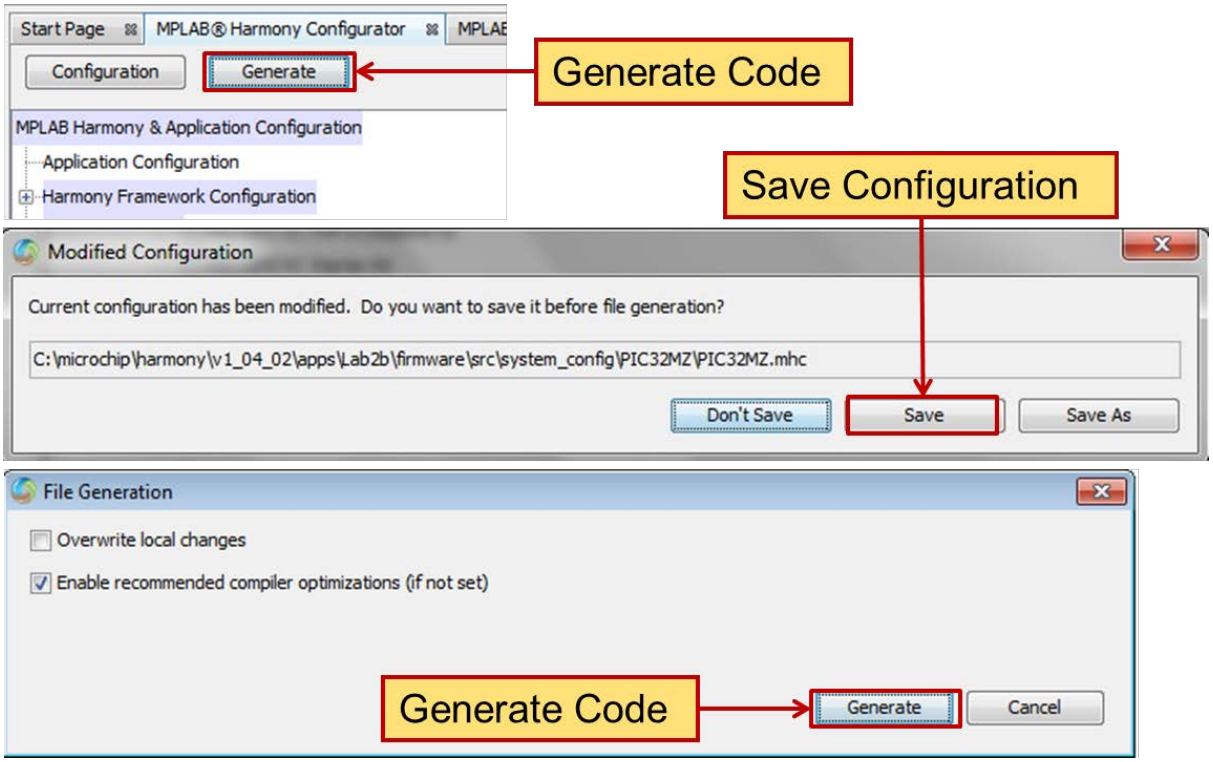
1. Select/Expand the Harmony Framework Configuration tree then select/expand USB Library to configure it (you may want to collapse the Drivers & System Services trees under Harmony Framework Configuration tree).
   a. Select/enable "Use USB Stack". (interrupt should be already selected)
   b. Next expand Select Host or Device Stack, and select USB Host (Beta Software). (the USB APIs have been improved over the legacy version)
   c. Verify that "Use MSD Host Driver" is already selected (default).

Step 1: Solution

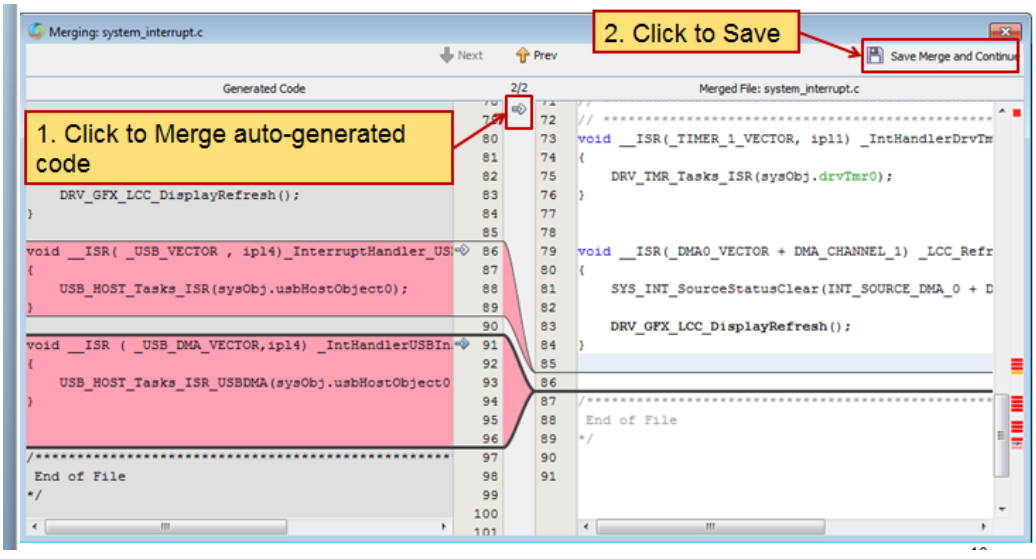
1. Enabled USB Host with MSD HOST as shown:
2. **Ensure** Interrupt Mode is selected.



Step 2a: At this point generate and save the configuration as shown:



Step 2b: Merge Auto-Generated code:



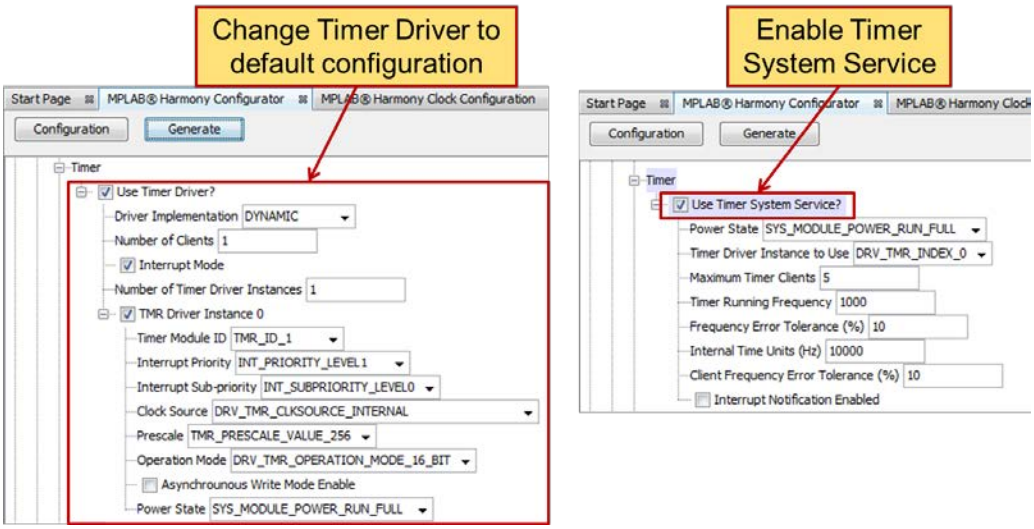
We have just added the USB Host with MSD functionality to the existing running MPLAB Harmony project.

Step 3: Objective – Reconfigure Timer Services

In this lab you will use the Dynamic Timer System Service instead of a single Static Timer Driver implemented in the previous labs.

1. Expand the MPLAB Harmony Framework Configuration tree, expand Drivers, and then expand Timer , and validate Use Timer Driver checkbox. Effectively, you will set the Timer Driver to its default state.
    a. Configure Driver Implementation → DYNAMIC and check the Interrupt Mode box
    b. Select and expand the TMR Driver Instance 0 tree
        - Set Timer Module ID → TMR_ID_1 (Timer1)
        - Set Operation Mode → DRV_TMR_OPERATION_MODE_16_BIT (16-bit mode)

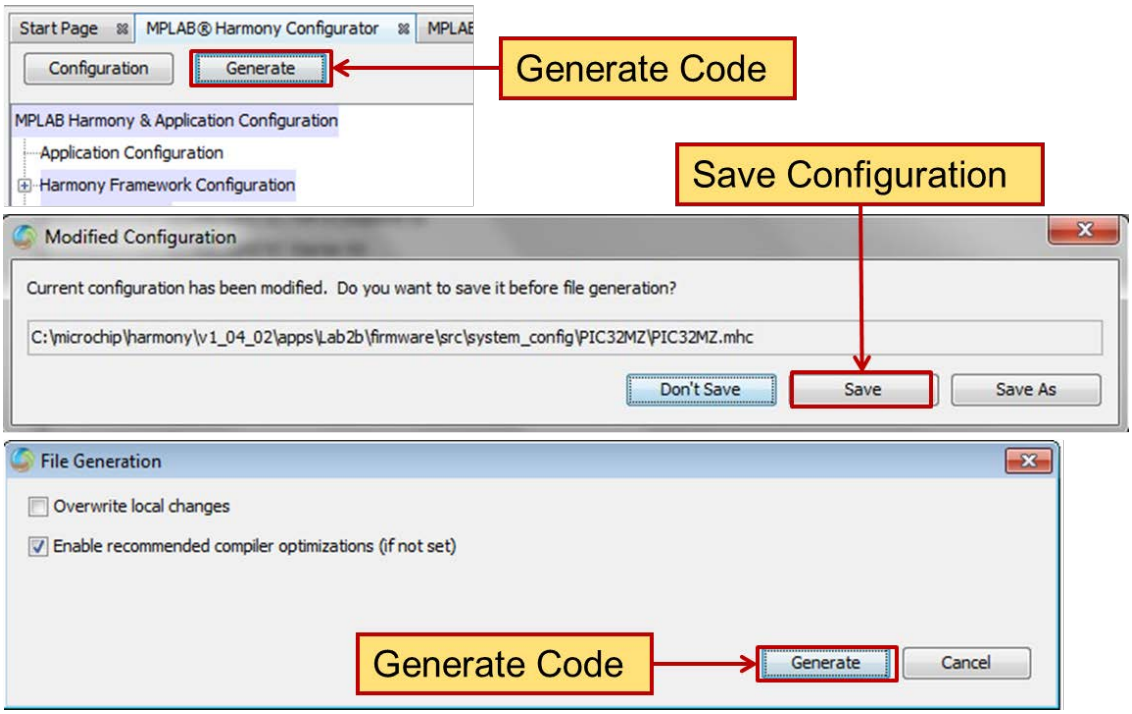
2. Now expand the MPLAB Harmony Framework Configuration tree, select & expand System Services then select/expand Timer to configure it.
    a. Check the Use Timer System Service checkbox .



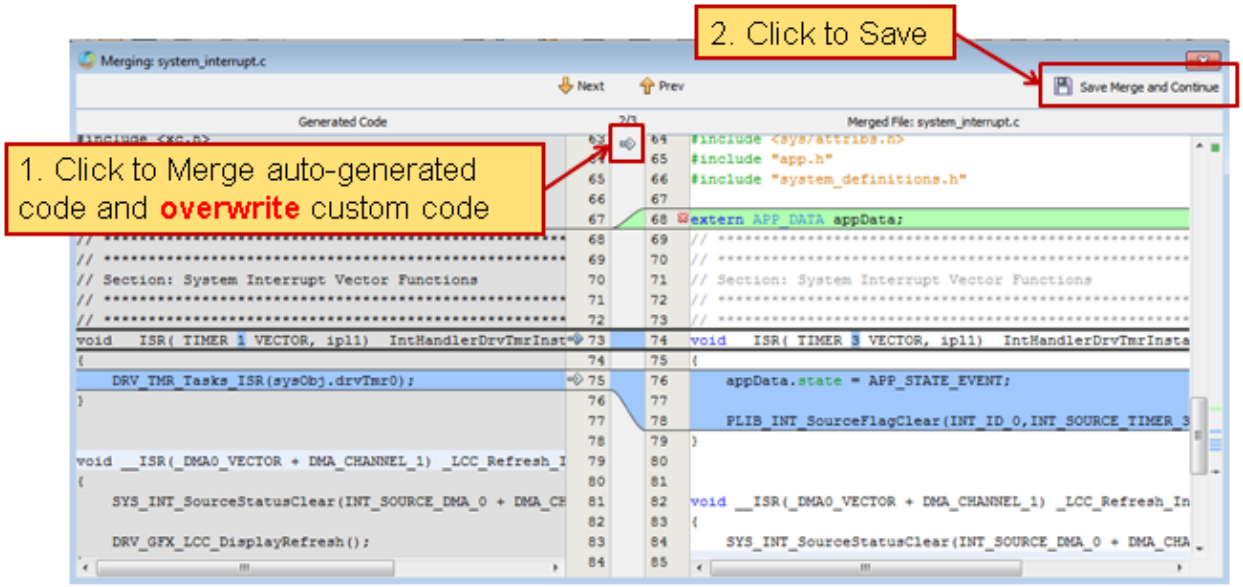
Step 3: Solutions

1. Using MHC, under Drivers, enable and configure Timer Driver to default configuration (which is DYNAMIC Driver).
2. Using MHC, under System Services, ensure the Timer System Service is selected.

Step 4a: Generate and save the configuration as shown:



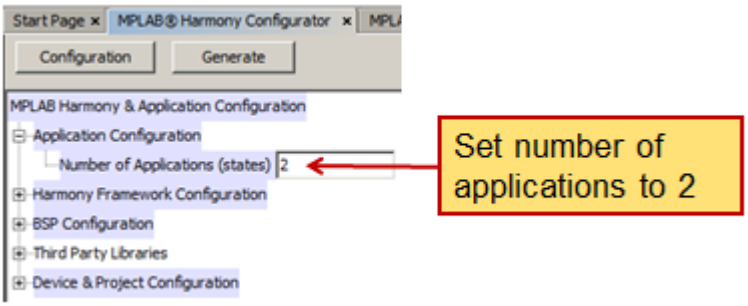
Step 4b: Merge Auto-Generated and overwrite custom code:



This tool is a great way to check and accept the code changes you just made against the existing source.

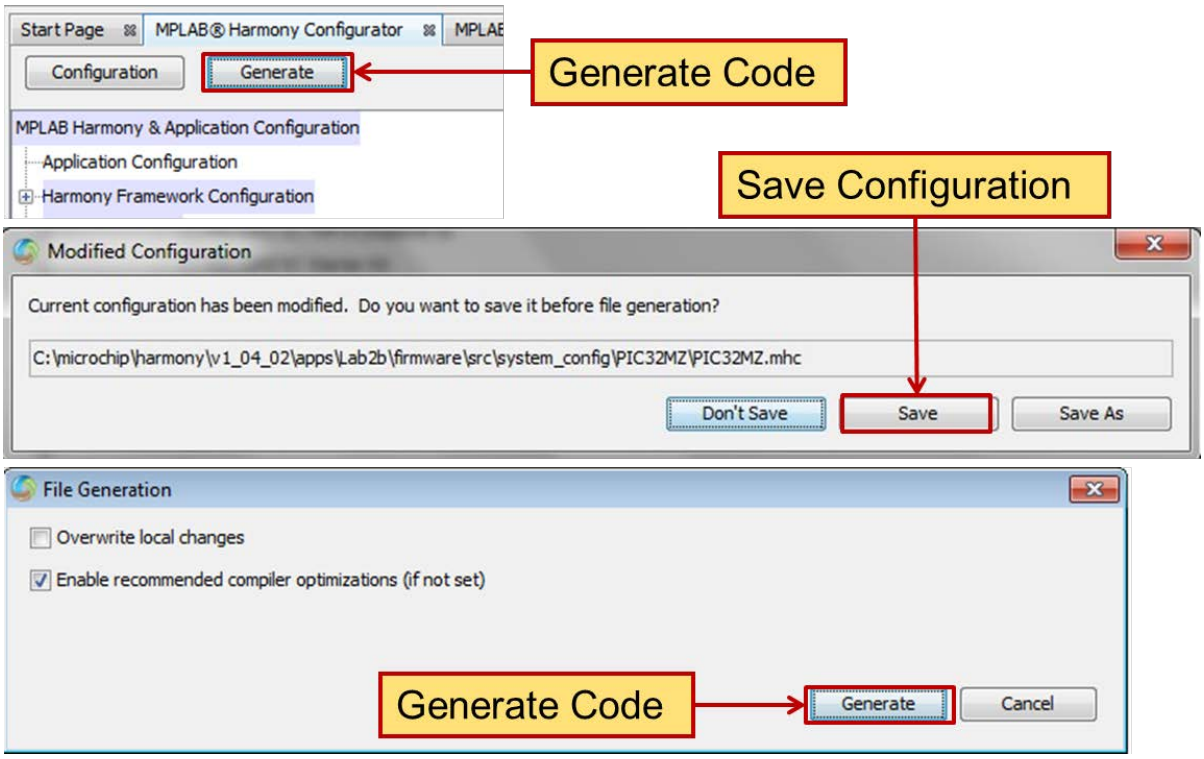
Step 5: Using MHC, set Application Configurations to "2" as shown.

This setting will create the framework for two Application state machines. We will retain the previous lab functionalities (blinky LED, UART TX and graphics library) as one application (app.c) and add USB Host MSD and File System for the second application (app1.c).

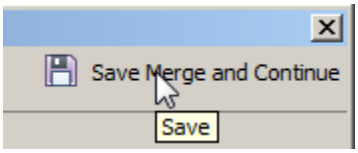


Step 6: Generate and save the configuration as shown.

At this point you should see two sets of nearly identical files in your project (app.h and app.c) and (app1.h and app1.c).

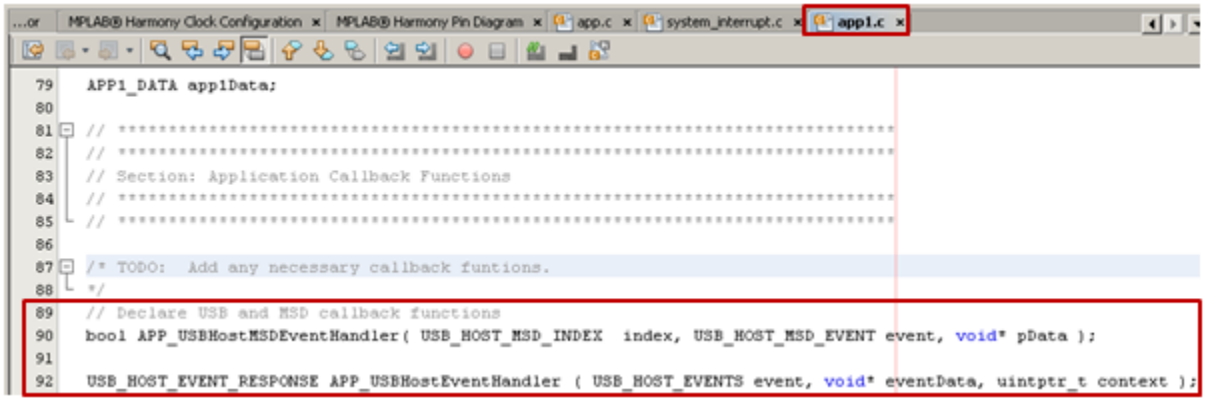


Then, keep all previous changes and merge the code :



Step 7: Objective – Declare & define USB and MSD callback functions

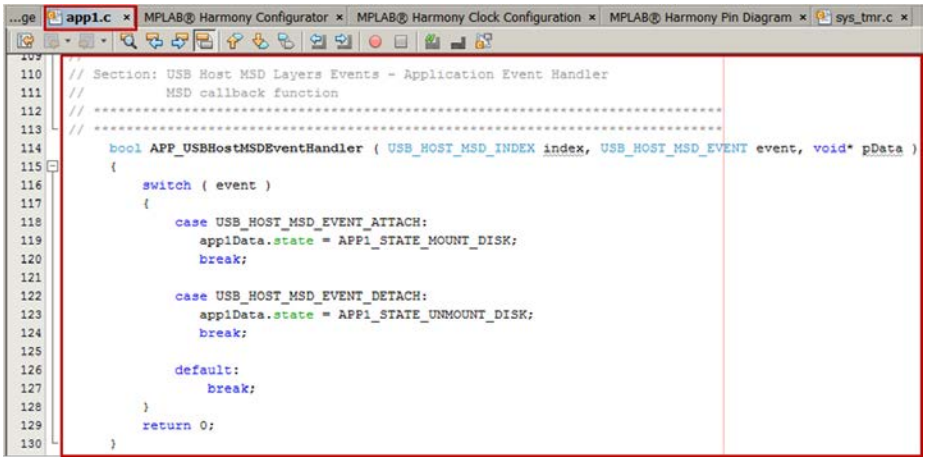
1. Open the app1.c file and declare the USB and MSD callback functions as shown.
   a. **Note**: Generally these two function prototype definitions would be included in the app1.h file. For this lab, you can include them in app1.c file.



You may want to copy & paste below code from the app1_solutionRTC.c file

```
APP1_DATA app1Data;
// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Functions
// *****************************************************************************
// *****************************************************************************
// Declare USB and MSD callback functions
bool APP_USBHostMSDEventHandler( USB_HOST_MSD_INDEX  index, USB_HOST_MSD_EVENT event, void* pData );

USB_HOST_EVENT_RESPONSE APP_USBHostEventHandler ( USB_HOST_EVENTS event, void* eventData, uintptr_t context );
```

2. Then, add the switch case state machine for the MSD related USB events under the // Section: Application Local Functions in the source file

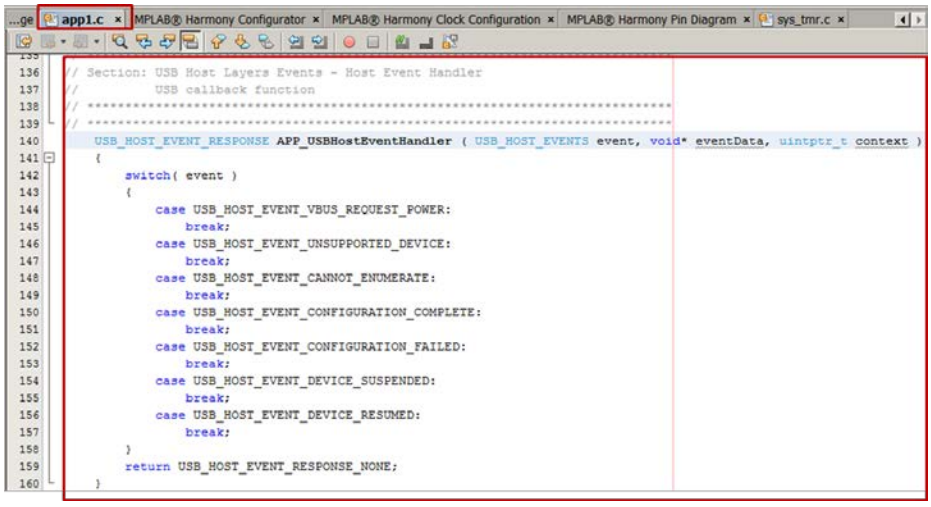


You may want to copy & paste below code from the app1_solutionRTC.c file

/* TODO: Add any necessary local functions.
***/**

```
// *****************************************************************************
// *****************************************************************************
// Section: USB Host MSD Layers Events - Application Event Handler
//          MSD callback function
// *****************************************************************************
// *****************************************************************************
bool APP_USBHostMSDEventHandler ( USB_HOST_MSD_INDEX index, USB_HOST_MSD_EVENT event, void* pData )
{
    switch ( event )
    {
        case USB_HOST_MSD_EVENT_ATTACH:
            app1Data.state = APP1_STATE_MOUNT_DISK;
            break;

        case USB_HOST_MSD_EVENT_DETACH:
            app1Data.state = APP1_STATE_UNMOUNT_DISK;
            break;

        default:
            break;
    }
    return 0;
}
```

3. Then, add the switch case state machine for the USB HOST related events below the code added in previous :



You may want to copy & paste below code from the app1_solutionRTC.c file.

```
// *****************************************************************************
// *****************************************************************************
// Section: USB Host Layers Events - Host Event Handler
//          USB callback function
// *****************************************************************************
// *****************************************************************************

USB_HOST_EVENT_RESPONSE APP_USBHostEventHandler ( USB_HOST_EVENTS event, void* eventData, uintptr_t context )
    {
        switch( event )
        {
            case USB_HOST_EVENT_VBUS_REQUEST_POWER:
                break;
            case USB_HOST_EVENT_UNSUPPORTED_DEVICE:
                break;
            case USB_HOST_EVENT_CANNOT_ENUMERATE:
                break;
            case USB_HOST_EVENT_CONFIGURATION_COMPLETE:
                break;
            case USB_HOST_EVENT_CONFIGURATION_FAILED:
                break;
            case USB_HOST_EVENT_DEVICE_SUSPENDED:
                break;
            case USB_HOST_EVENT_DEVICE_RESUMED:
                break;
        }
        return USB_HOST_EVENT_RESPONSE_NONE;
    }
```

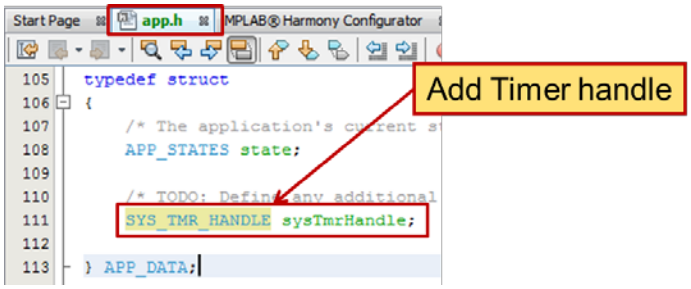
Step 8: Objective – Start Timer Service as a one second event

Before changing our new files app1.c and app1.h, we just need to make a few more changes to app.c and app.h files :

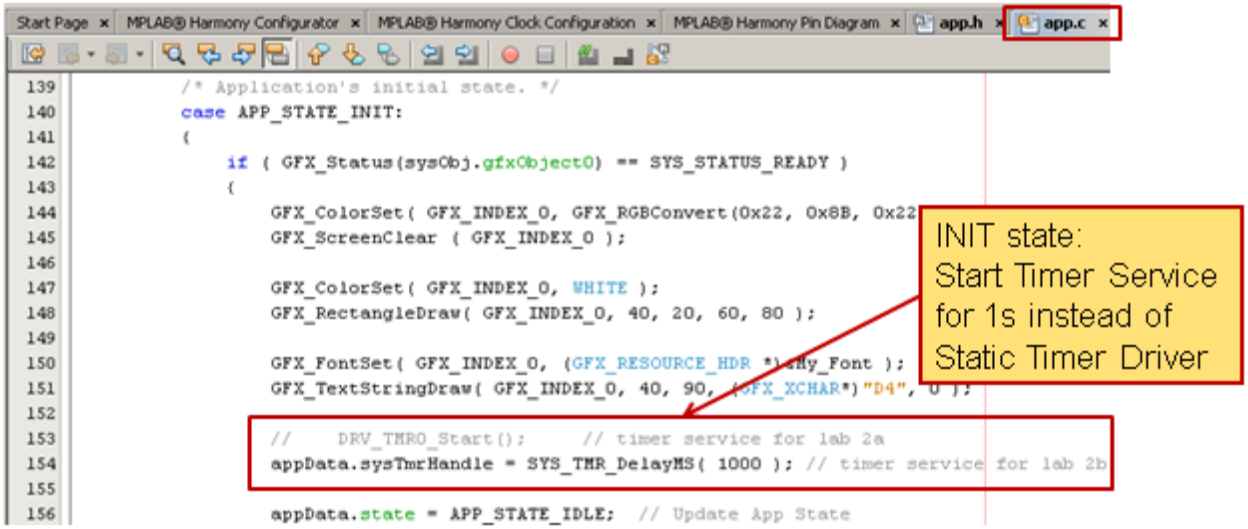
1. First, open app.h file and declare a SYS_TMR_HANDLE sysTmrHandle; (Timer handle) element in struct APP_DATA after the element APP_STATES state;
2. Second, open app.c file and locate case statement APP_STATE_INIT in the APP_Tasks function. Within this case statement you will add code to start the Timer Service for a one second delay :
    a. Remove or comment out the DRV_TMR0_Start(); function call.
    (Remember that this function was used when we implemented a Static Timer Driver for the previous labs).
    b. Replace this call (within this same **If** statement) with a function call to start the Timer Service for a one second delay.
    (Refer to the Integrated Help “Timer System Service Library”, by right double clicking on Use Timer System Service
    Timer System Service Library → Library Interface → Timed Delay Functions → SYS_TMR_DelayMS).

Step 8: Solutions

1. Declare a SYS_TMR_HANDLE sysTmrHandle (Timer handle) element in struct APP_DATA.



2. Start the Timer Service for a one second delay (1000 millisecond ticks)



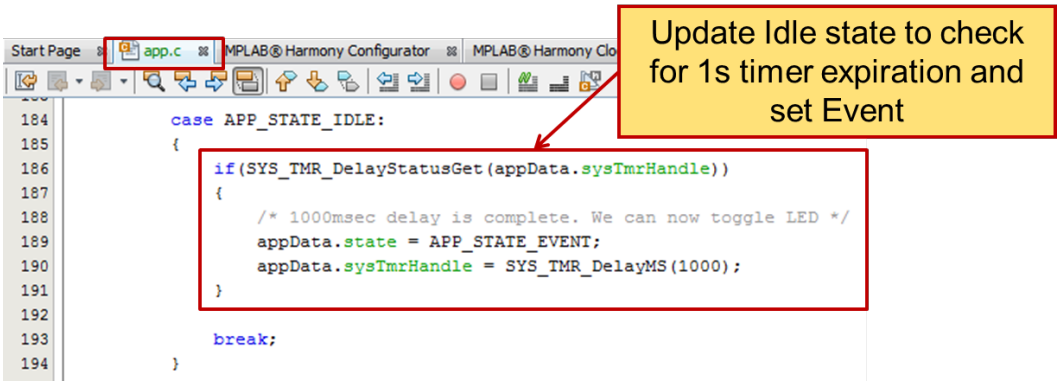
Step 9: Objective – Use Timer Service as 1 second event

1. Open app.c file and locate case statement APP_STATE_IDLE. Within this case statement add code to do the following:
   a. Test **If** Timer Service has expired using SYS_TMR_DelayStatusGet(arg). If test is TRUE, then:
      i. Update appData.state to APP_STATE_EVENT
         Hint: Remember that you defined this state in app.h file
      ii. Restart the Timer Service for one second delay

==========

Step 9: Solution

1. Add **If** statement and test for Timer Service expiration.
   a. If test is TRUE, update application state and restart Timer Service for one second delay.

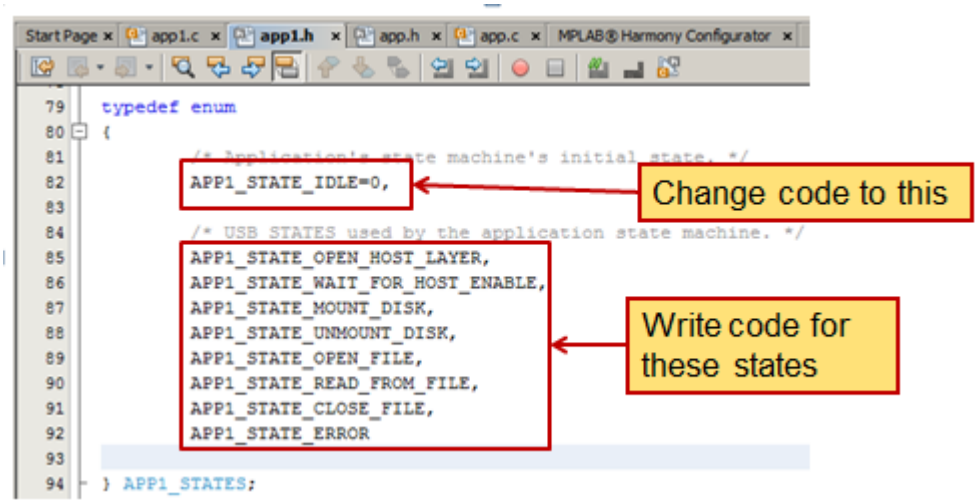


You may want to copy & paste below code from the app_solutionRTC.c file.

```
        if ( SYS_TMR_DelayStatusGet( appData.sysTmrHandle) )
        {
            /* 1000ms delay is complete. We can now toggle LED */
            appData.state = APP_STATE_EVENT;
            appData.sysTmrHandle = SYS_TMR_DelayMS( 1000 );
        }
```

Step 10a: Open app1.h file and add nine new USB MSD Application States as shown below.

(Note: The first auto generated application state "APP1_STATE_INIT=0," must be changed to "APP1_STATE_**IDLE**=0,").

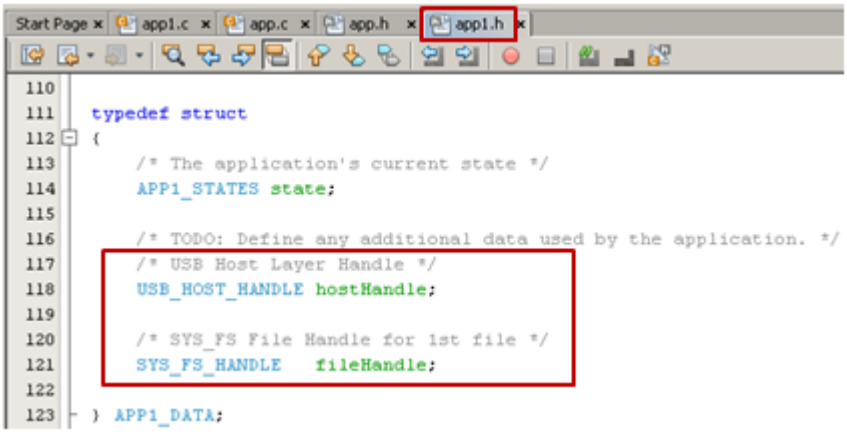


You may want to copy & paste below code from the app1_solutionRTC.h file.

```
typedef enum
{
        /* Application's state machine's initial state. */
    APP1_STATE_IDLE=0,

        /* USB STATES used by the application state machine. */
    APP1_STATE_OPEN_HOST_LAYER,
    APP1_STATE_WAIT_FOR_HOST_ENABLE,
    APP1_STATE_MOUNT_DISK,
    APP1_STATE_UNMOUNT_DISK,
    APP1_STATE_OPEN_FILE,
    APP1_STATE_READ_FROM_FILE,
    APP1_STATE_CLOSE_FILE,
    APP1_STATE_ERROR

} APP1_STATES;
```

Step 10b: Next, also in app1.h file,

a. add USB_HOST_HANDLE structure element as shown below.
b. add SYS_FS_HANDLE structure element as shown below.

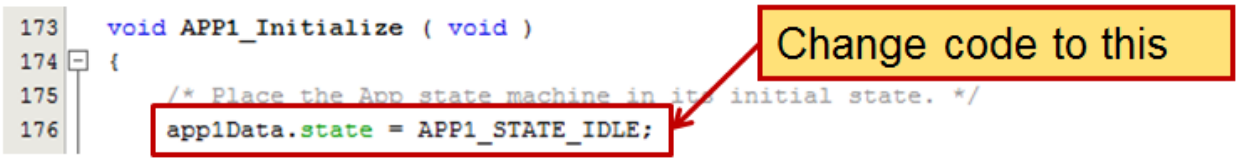


You may want to copy & paste below code from the app1_solutionRTC.h file.

```
typedef struct
{
    /* The application's current state */
    APP1_STATES state;

    /* TODO: Define any additional data used by the application. */
    /* USB Host Layer Handle */
    USB_HOST_HANDLE hostHandle;

    /* SYS_FS File Handle for 1st file */
    SYS_FS_HANDLE   fileHandle;

} APP1_DATA;
```

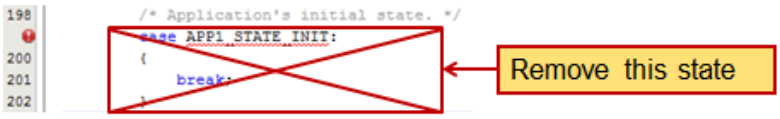
Note: Step 11 has many code development requirements. Please refer to the solution file (app1_solution.c) if you elect to copy and paste some **or all of the code** (lots of changes are needed).

Step 11a: Open app1.c file and in the void APP1_Initialize (void) function change app1Data.state default state APP1_STATE_INIT to APP1_STATE_IDLE



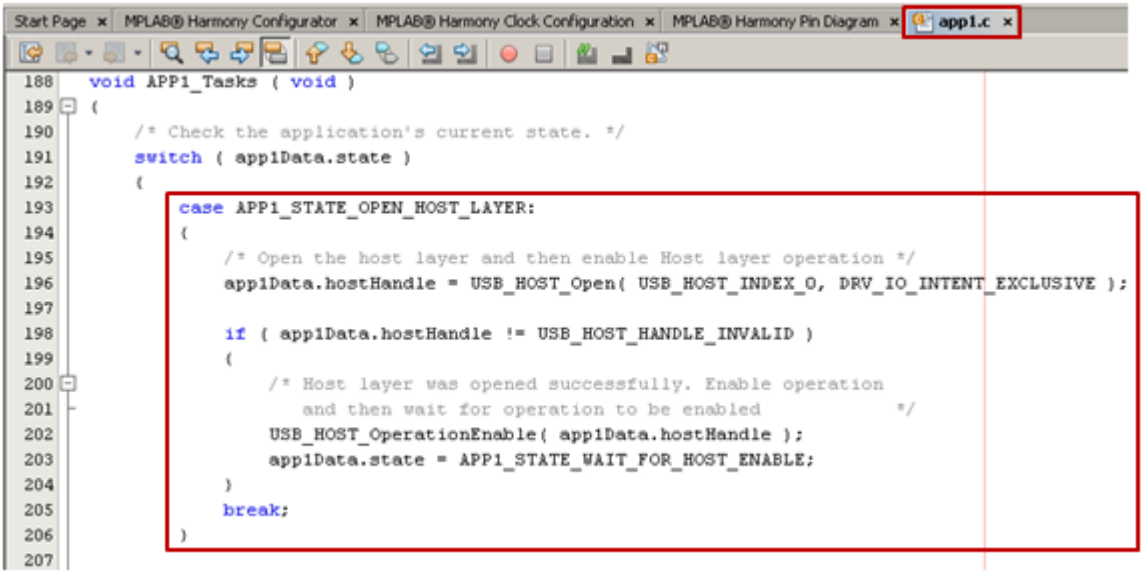

```
173  void APP1_Initialize ( void )
174  {
175      /* Place the App state machine in its initial state. */
176      app1Data.state = APP1_STATE_IDLE;
```

Step 11b: continue with app1.c file. First, we need **to remove** the existing APP1_STATE_INIT state from the (void) APP1_Tasks (void) function :



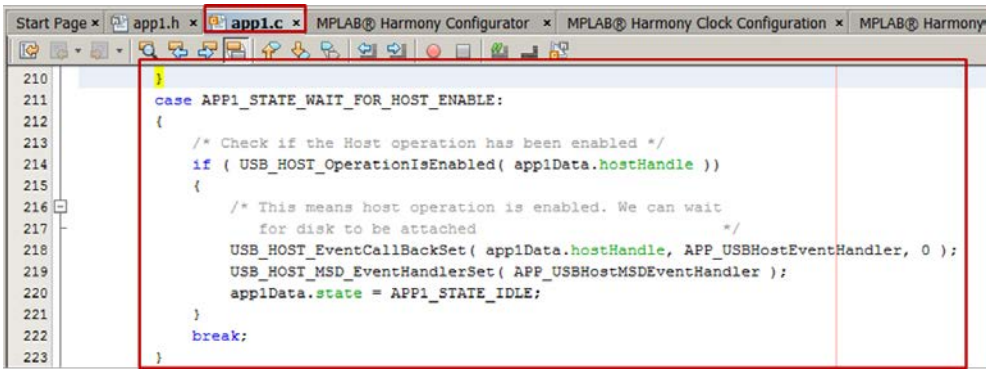

```
198      /* Application's initial state. */
         case APP1_STATE_INIT:
200      {
201          break;
202      }
```

Step 11c: continue with app1.c file. and add a new USB MSD Application State in the existing APP1_Tasks () function :
STATE: APP1_STATE_OPEN_HOST_LAYER

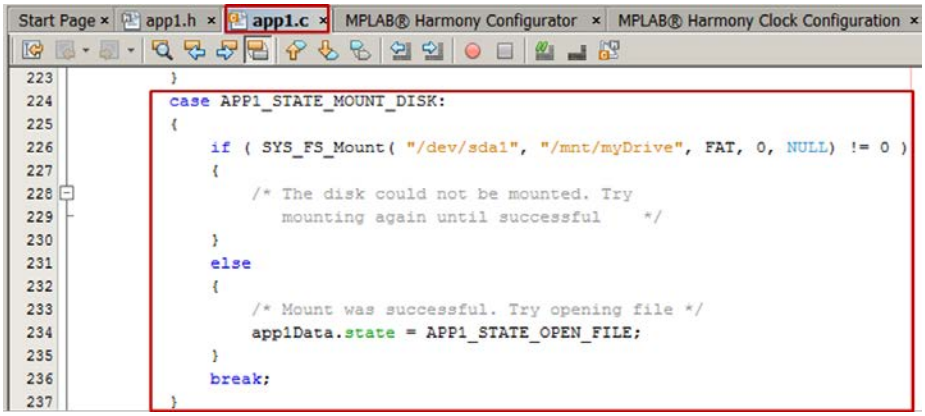


```
188  void APP1_Tasks ( void )
189  {
190      /* Check the application's current state. */
191      switch ( app1Data.state )
192      {
193          case APP1_STATE_OPEN_HOST_LAYER:
194          {
195              /* Open the host layer and then enable Host layer operation */
196              app1Data.hostHandle = USB_HOST_Open( USB_HOST_INDEX_0, DRV_IO_INTENT_EXCLUSIVE );
197
198              if ( app1Data.hostHandle != USB_HOST_HANDLE_INVALID )
199              {
200                  /* Host layer was opened successfully. Enable operation
201                     and then wait for operation to be enabled          */
202                  USB_HOST_OperationEnable( app1Data.hostHandle );
203                  app1Data.state = APP1_STATE_WAIT_FOR_HOST_ENABLE;
204              }
205              break;
206          }
207
```

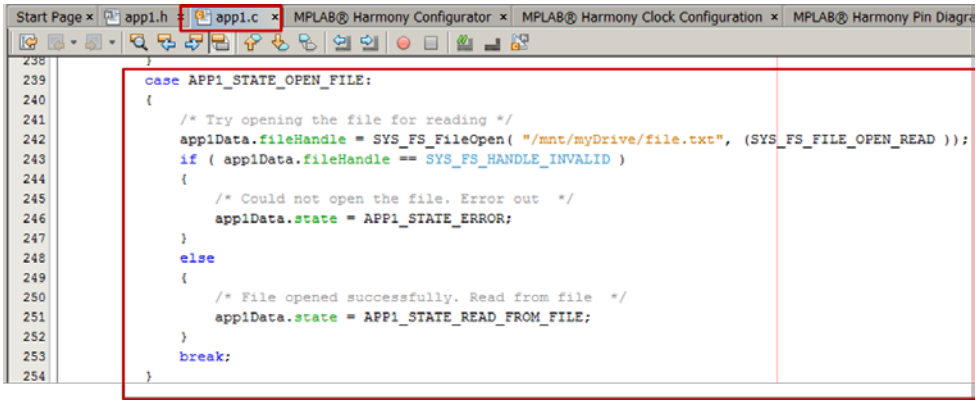
Step 11d: continue with app1.c file and add another USB MSD Application State :
STATE: APP1_STATE_WAIT_FOR_HOST_ENABLE



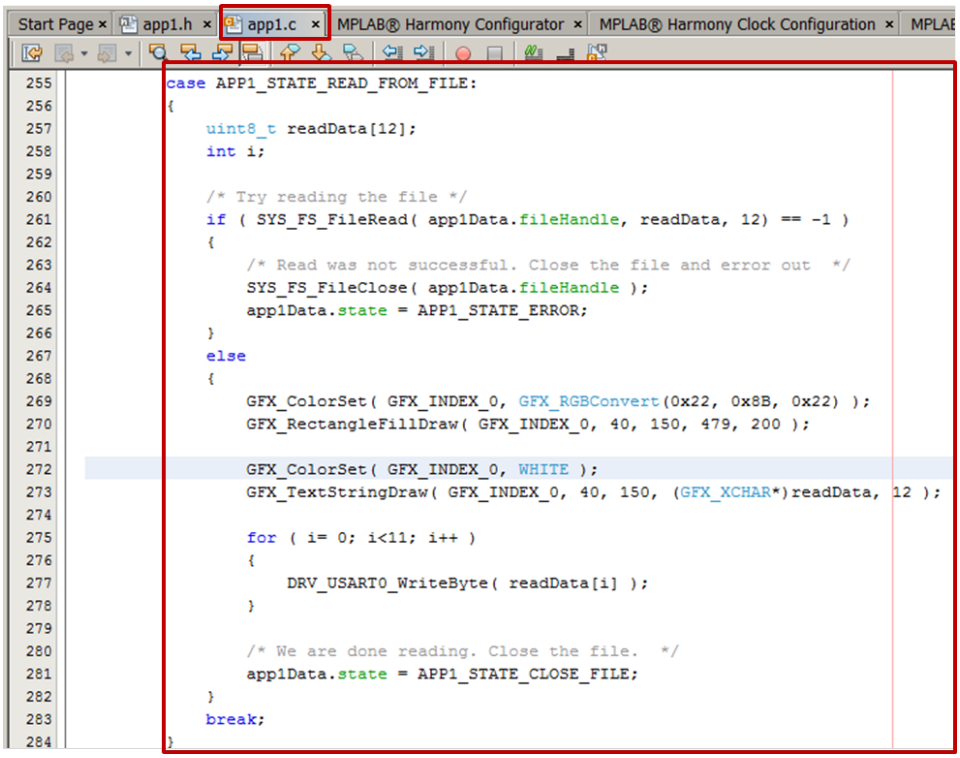
Step 11e: continue with app1.c file and add another USB MSD Application State
STATE: APP1_STATE_MOUNT_DISK



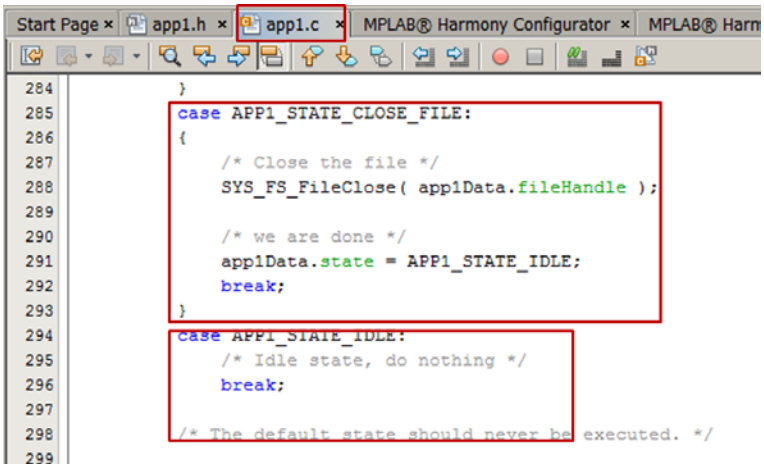
Step 11f: continue with app1.c file and add another USB MSD Application State
STATE: APP1_STATE_OPEN_FILE



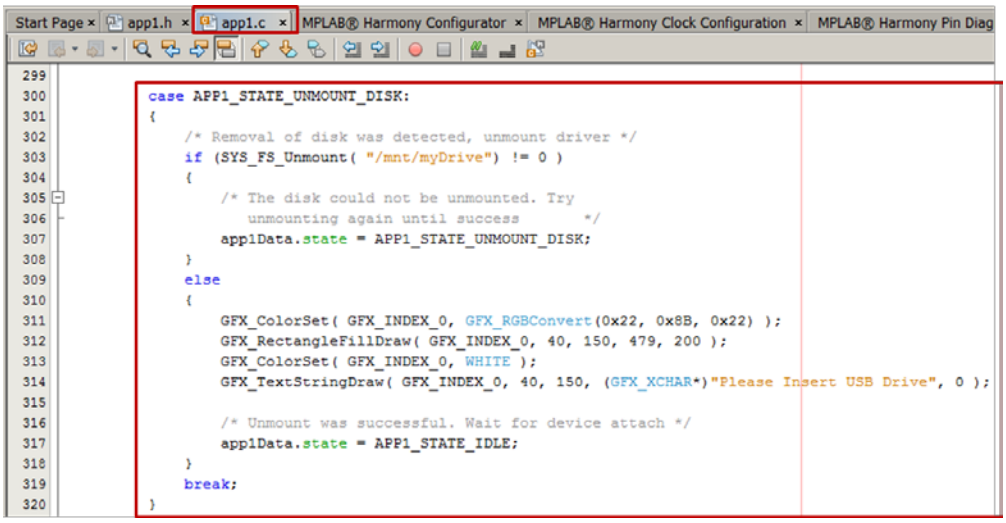
Step 11g: continue with app1.c file and add another USB MSD Application State STATE: APP1_STATE_READ_FROM_FILE



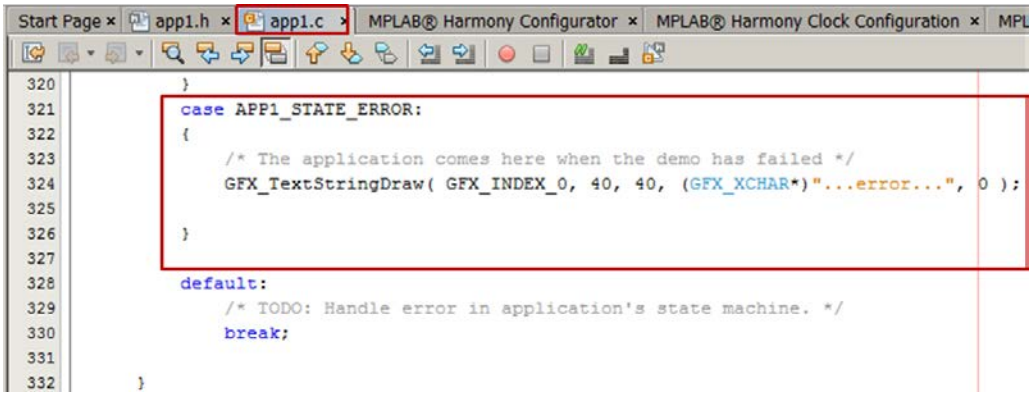
Step 11h: continue with app1.c file and add another USB MSD Application State STATE: APP1_STATE_CLOSE_FILE and APP1_STATE_IDLE



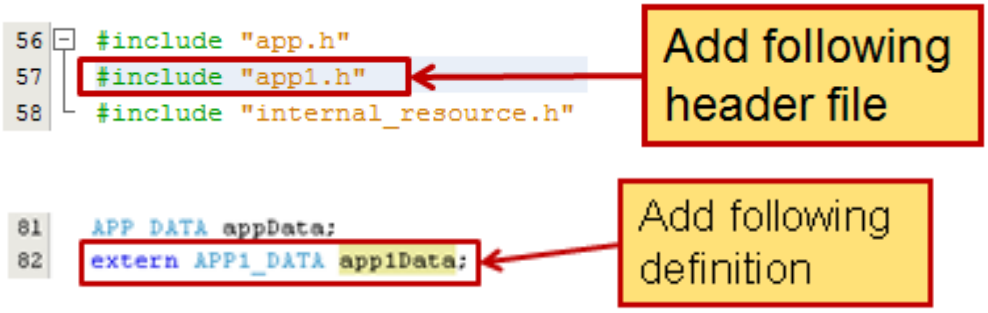
Step 11i: continue with app1.c file and add another USB MSD Application State STATE: APP1_STATE_UNMOUNT_DISK



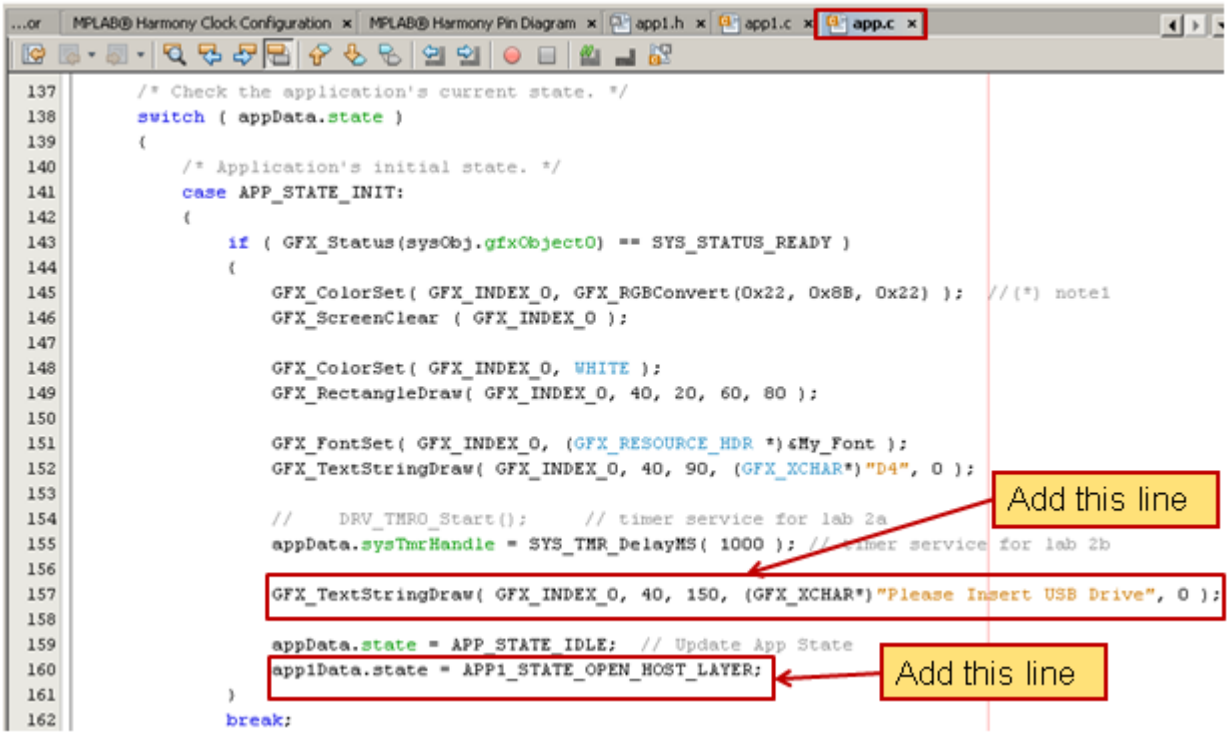
Step 11j: continue with app1.c file and add another USB MSD Application State STATE: APP1_STATE_ERROR



Step 12a: Open app.c file and do the following **2 changes** :



Step 12b: In app.c file add the 2 following lines :
STATE: APP_STATE_INIT



Build the project to make sure there is no error at this step : 

Step 13:

1. Connect the **USB Pen Drive to your PC.**
2. Copy the “file.txt” from the Lab2b directory to the USB pen drive root level.

The file.txt contains the 12 characters string **MPLABHarmony** .
If you want to change this string, make sure it is exactly the same length (12 characters)

You can now build, program, and run the application by pressing 

Once the application is running you should see the LCD like A] below.

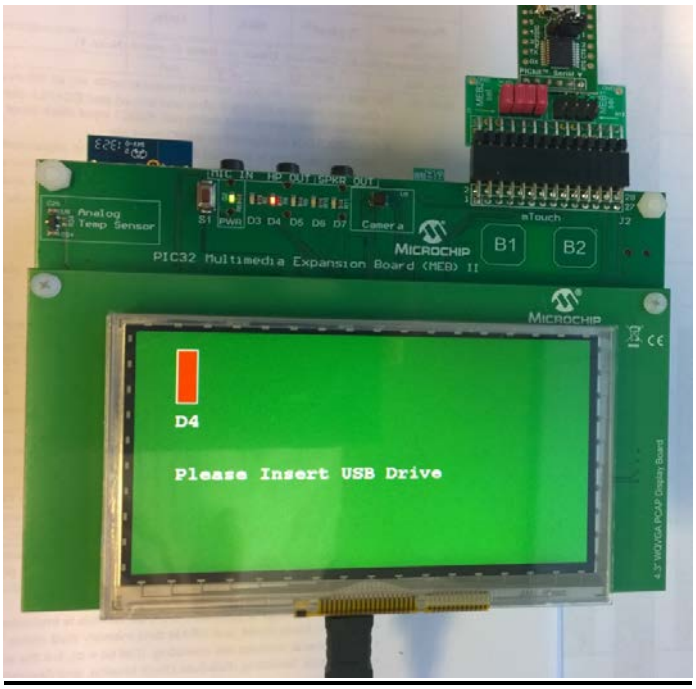
The application is waiting for a USB memory stick insertion.
Insert the USB memory stick into the USB A connector located on the PIC32MZ EC starter kit :

Once the USB pen drive has been inserted, the message **MPLABHarmony** (or the one you stored in the text file file.txt), should be displayed on the MEB II glass and is also transmitted on UART TX.

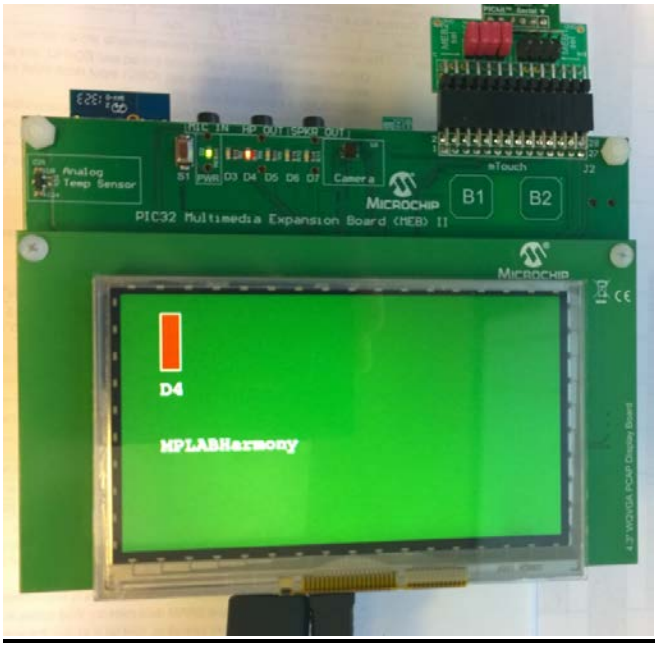
See the next page for the expected results displayed on the PIC32MZ EC Starter Kit.

1. Text should be displayed on MEB II.
2. Text should also be displayed on terminal application.
3. LED continues to blink with status also displayed on the MEB II TFT LCD display.

A] Display *before* USB Pen Drive is inserted into PIC32MZ EC Starter Kit



B] Display *after* USB Pen Drive is inserted into PIC32MZ EC Starter Kit



LAB 3: Migration in MPLAB® Harmony

LAB 3: Migration in MPLAB® Harmony

Purpose:

After completing Lab 3, you will gain a better understanding on how to use the MPLAB X IDE and MHC to seamlessly migrate your application across the PIC32 MCU product families.

PIC32MZ with MEB II → PIC32MX with MEB I

Procedure:

It is unlikely you will have both hardware platforms required for this lab. It is still useful for you to experience the steps required to migrate a design from one hardware platform to another.

For Lab 3, no code development is required. We will take the resultant Lab 2b solution, running on the PIC32MZ MCU and its respective hardware, and seamlessly migrate to the PIC32MX MCU and its respective hardware. This is basically a two-part process.

All nine steps must be completed before you will be ready to build, download and run the application. Here are the steps you will work through:

- **Part 1: Create New Configuration**
  - Step 1 – Create a new MPLAB X Configuration
  - Step 2 – Choose Device and Tools
  - Step 3 – Set new "PIC32MX" configuration as active
- **Part 2: Configure PIC32MX and Harmony Components**
  - Step 4a – With MHC, Select PIC32MX Configuration
  - Step 4b – With MHC, Configure PIC32MX BSP
  - Step 5 – With MHC, Configure PIC32MX Clocks
  - Step 6a – With MHC, Configure PIC32MX UART Driver
  - Step 6b – With MHC, Configure PMP Driver
  - Step 7 – With MHC, Configure Graphics LibraryStep 8 – With MHC, Configure USB Host MSD Library
  - Step 9 – With MHC, Generate and Save code

Step 1: Objectives – Create new MPLAB® X Configuration

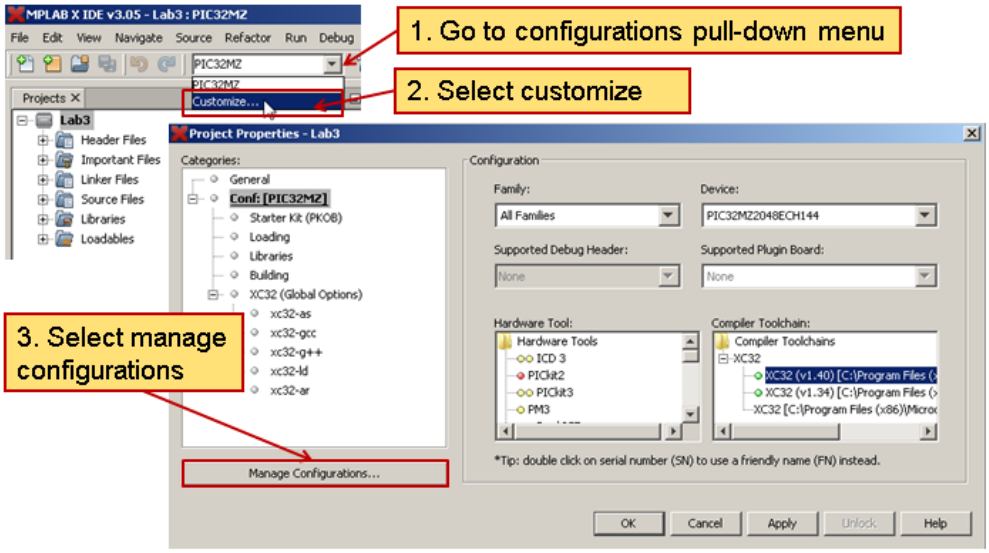
1. First, **close** the Lab2**b** project and **open** the Lab**3** project :

File > Close Project (Lab2b)

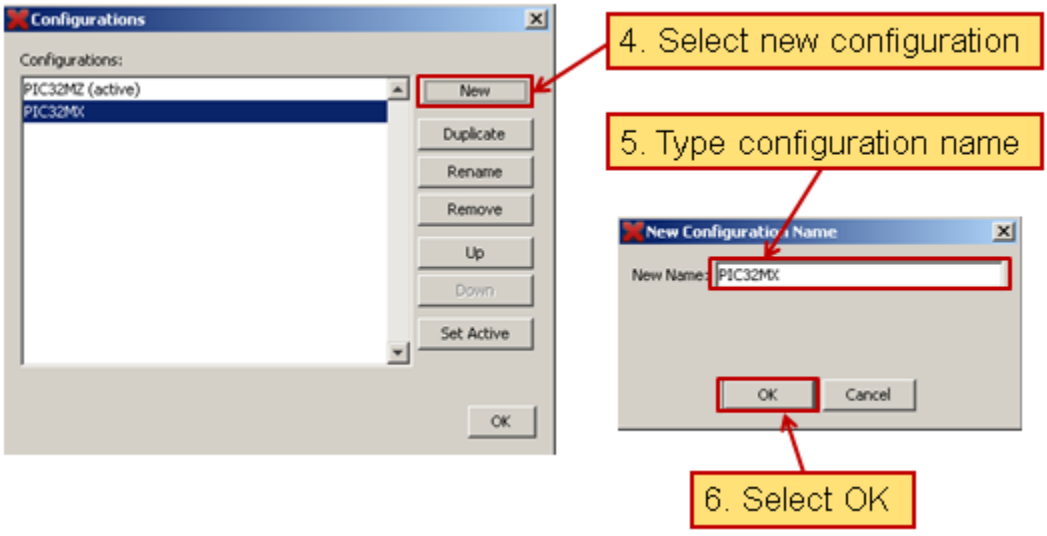
File > Open Project > C:\microchip\harmony\v1_05\apps\Lab3\firmware\Lab3.X

2. Set Lab3 as Main Project to be able to use MHC : **Set as Main Project**
3. Enable MHC : **Tools > Embedded > MPLAB Harmony Configurator**

i. Select Configuration Menu.
ii. Select Customize.
iii. Select Manage Configurations.



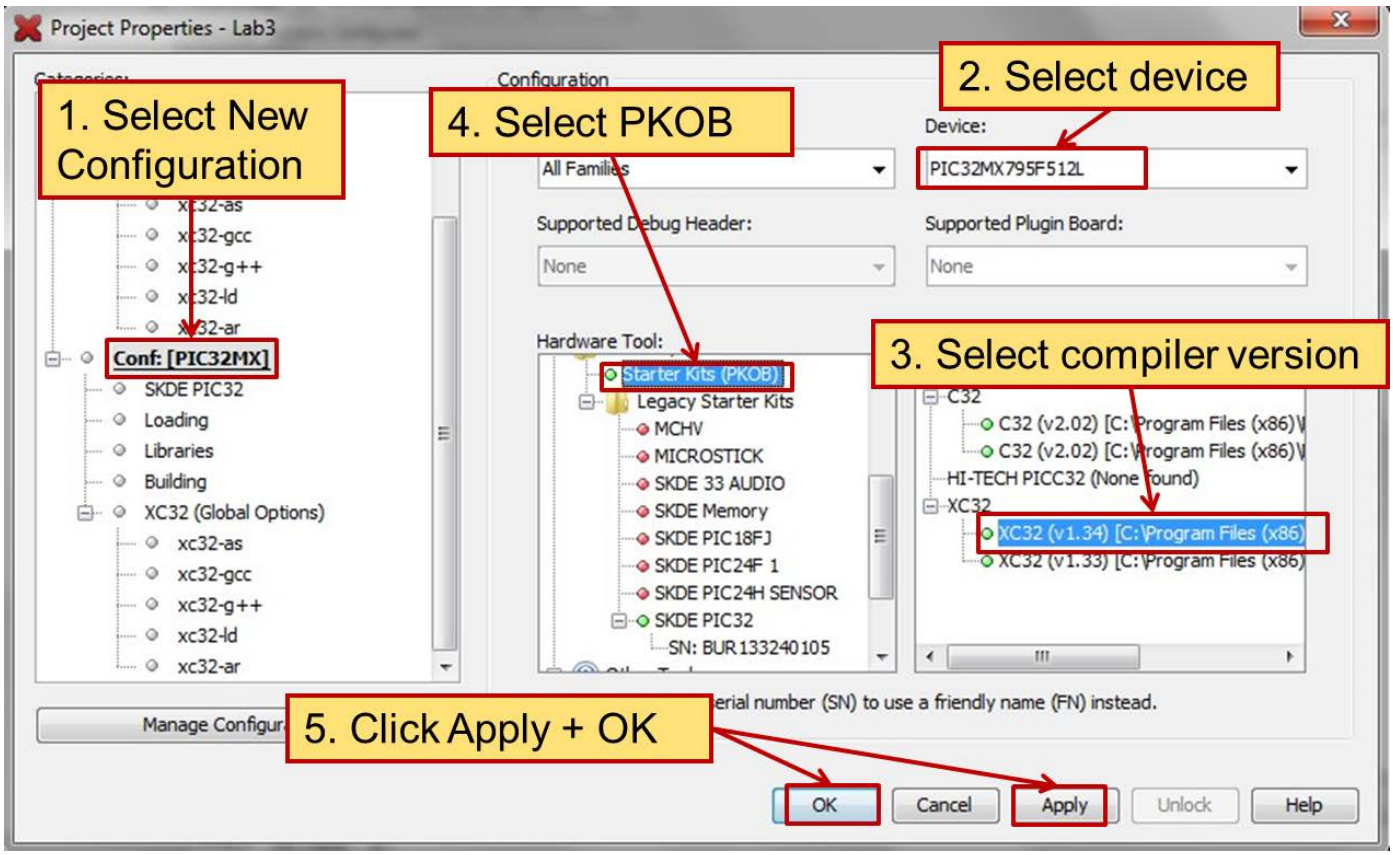
iv. Select New Configuration.
v. Type new Configuration name → **PIC32MX**
vi. Click **OK**.



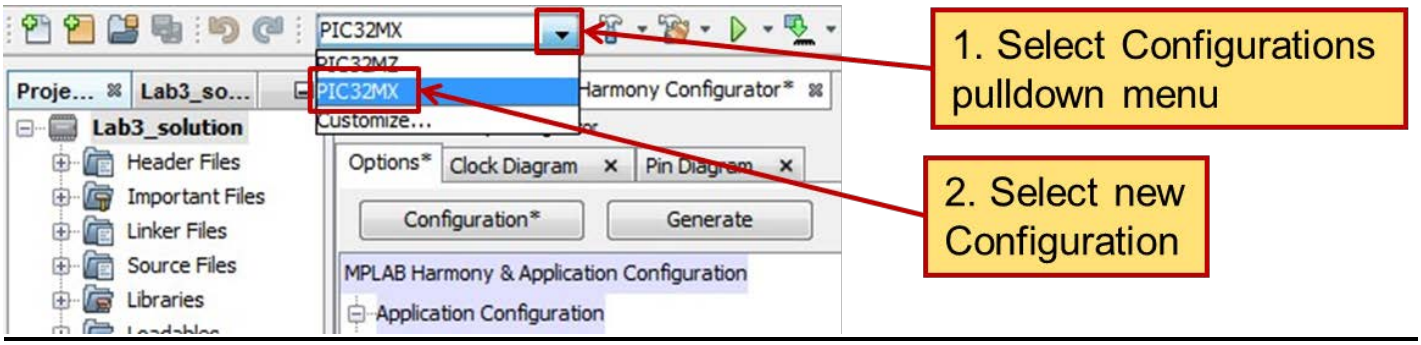
Step 2: Choose Device, compiler and tool/starterkit to use

a. Follow the steps as shown:

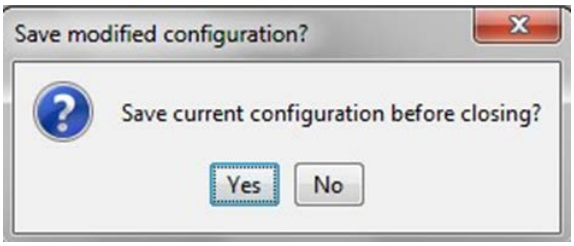
- PIC32MX795F512L
- XC32 v1.34 or more
- SKDE PIC32 where you see the S/N : **BUR…..**



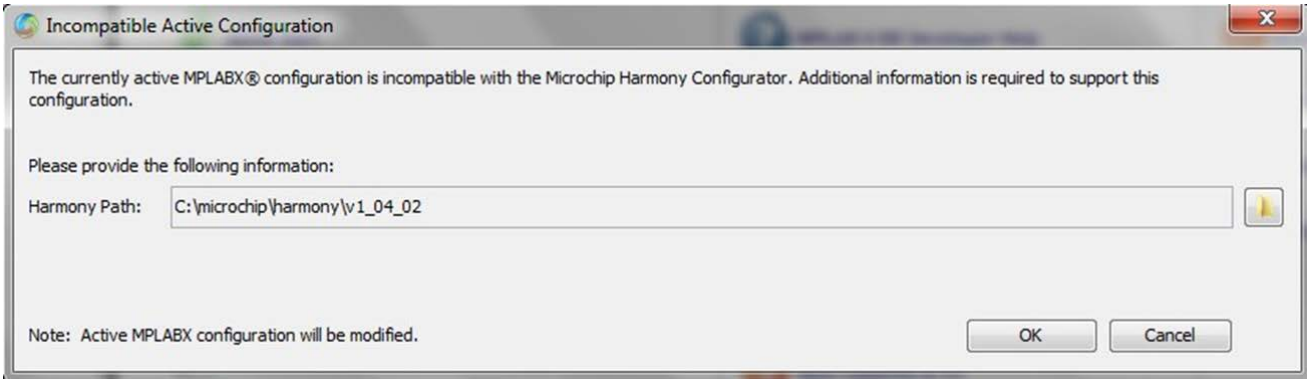
Step 3: Set new "PIC32MX" configuration as active



If you see this message, just click **YES** :

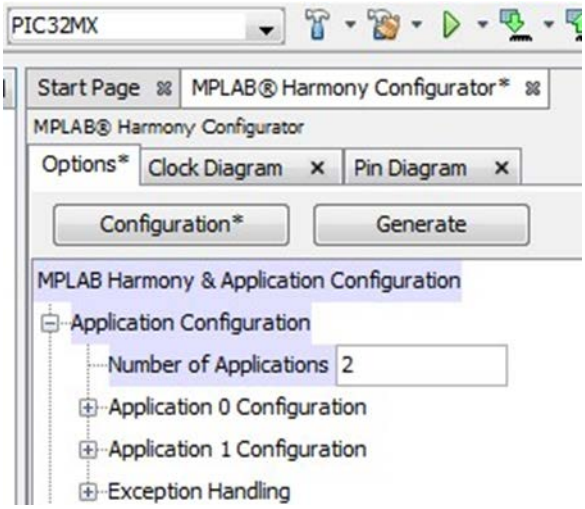


If you see this message, just click **OK** :



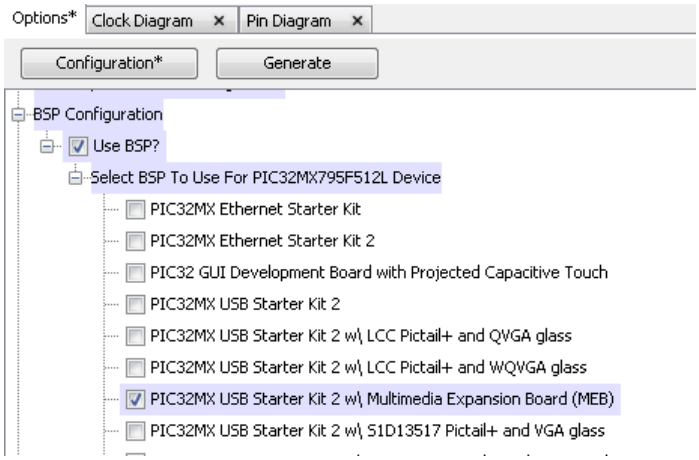
Step 4a: Using MHC, Configure PIC32MX

1. If MHC is open, it will restart when the new configuration becomes active.
2. If MHC is closed, start it manually.
3. Now expand Application Configuration and set at 2 (we use 2 state machines), and then press ENTER :



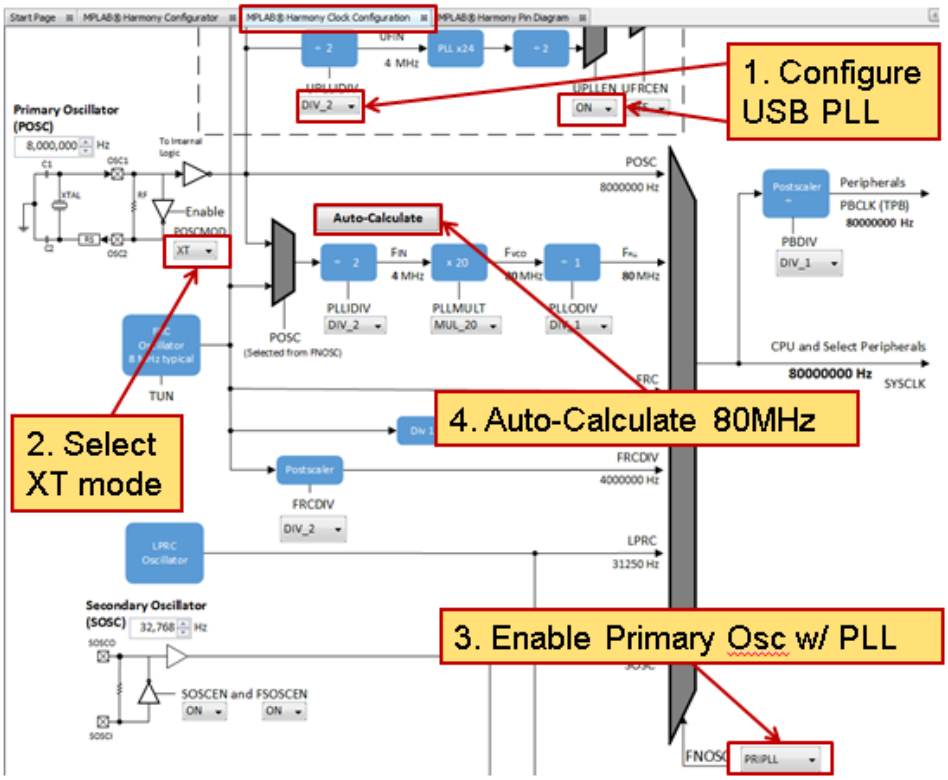
Step 4b: Configure BSP as shown

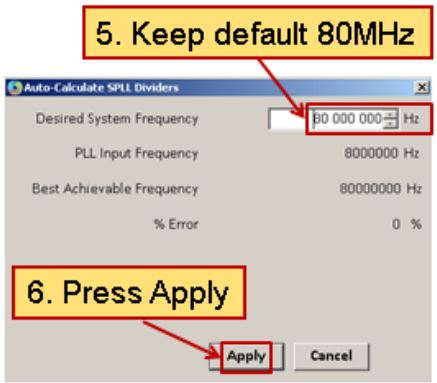
1. First, expand the BSP Configuration tree and select the correct BSP (PIC32MX USB Starter Kit 2 w/Multimedia Expansion Board (MEB))



Step 5: Set PIC32MX Clocks (With MPLAB® Harmony Clock Configurator)

1. Configure USB PLL as shown.
2. Select Primary Oscillator mode to “XT mode”.
3. Select Primary Oscillator w/PLL.
4. Auto-Calculate.

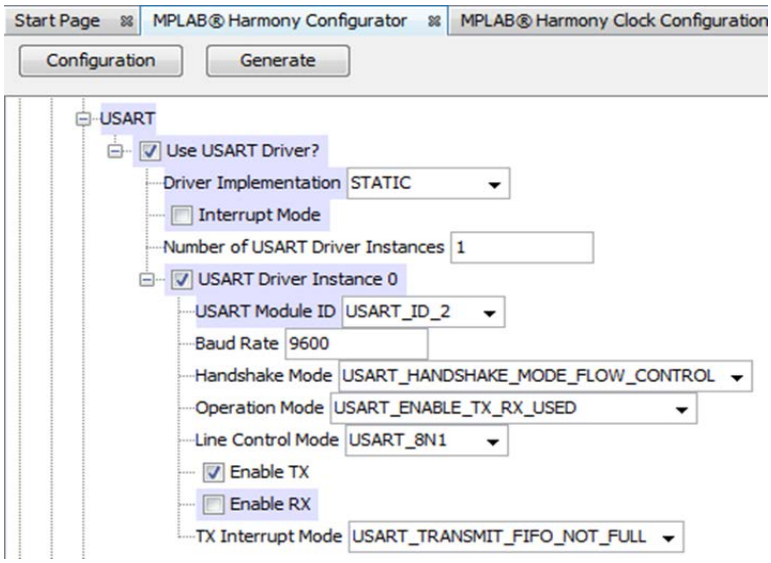




Step 6a: Configure UART Driver

1. Expand Harmony Framework Configuration tree, select/expand Drivers and locate USART.

   Set USART Driver as shown (STATIC, Interrupt Mode (**disabled),** USART_ID_2, ENABLE RX (**disabled**)).



Step 6b: Configure PMP Driver

1. Expand Harmony Framework Configuration tree, select/expand Drivers and locate PMP.

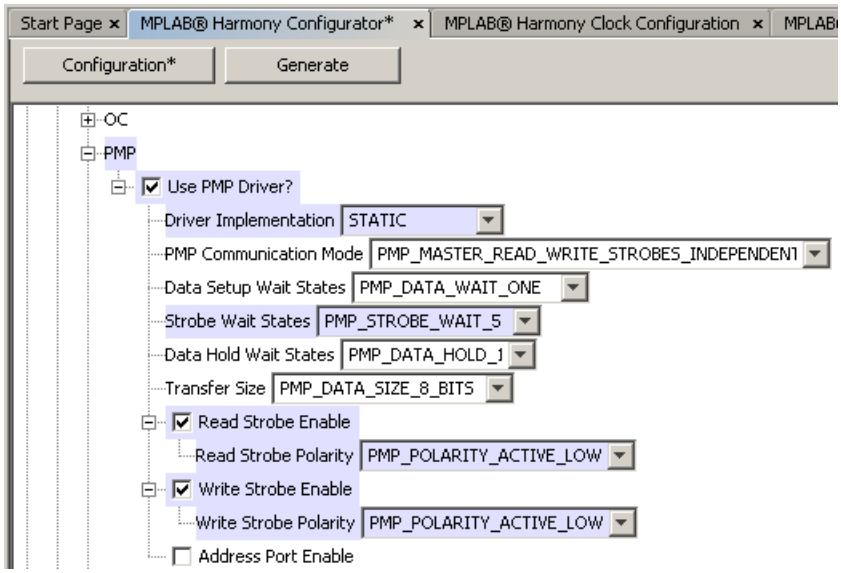
   Set PMP Driver as shown :

   Driver implementation : STATIC,

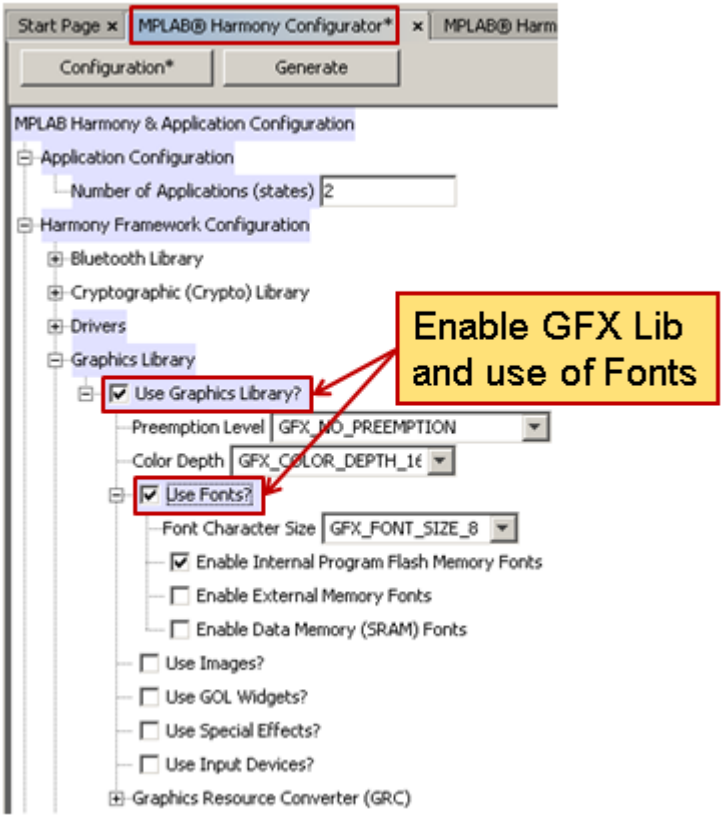
   Strobe Wait states : PMP_STROBE_WAIT_5

   Select Read Strobe Enable with Polariy PMP_POLARITY_ACTIVE_LOW

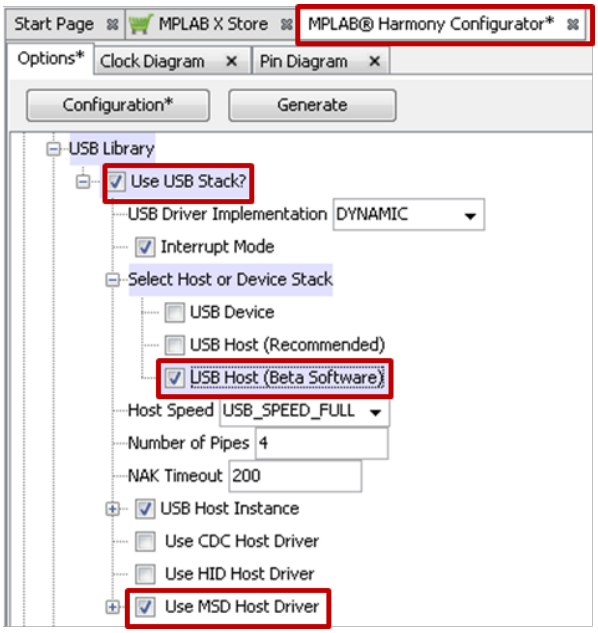
   Select Write Strobe Enable with Polarity PMP_POLARITY_ACTIVE_LOW



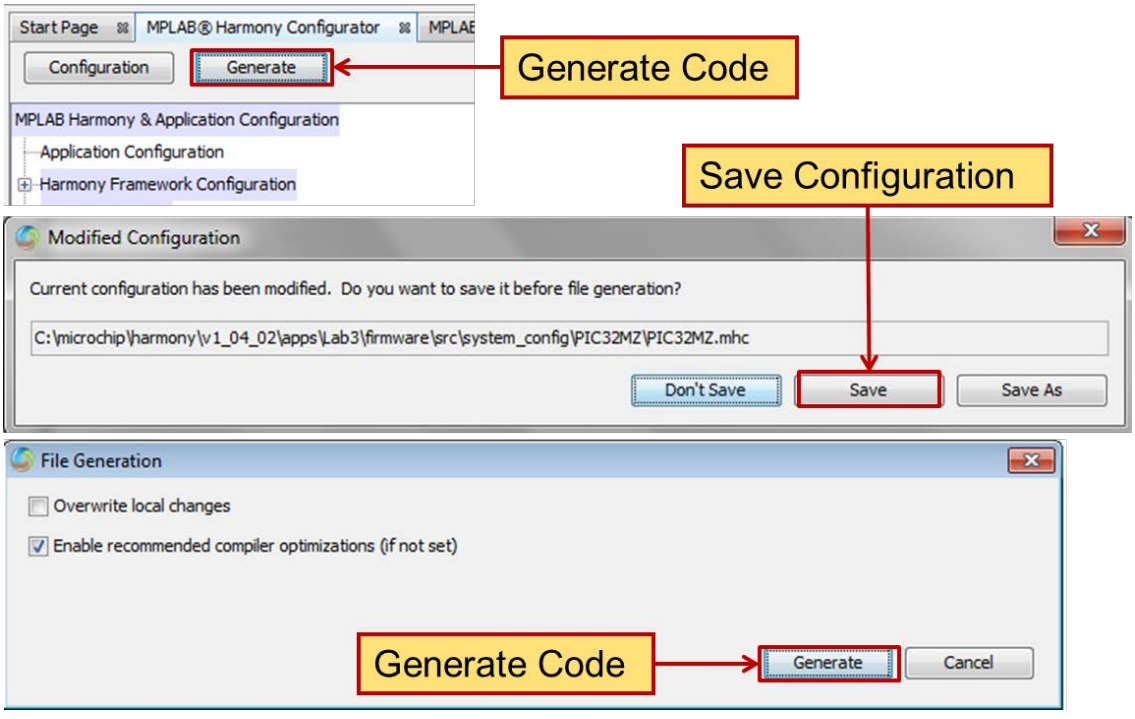
Step 7: Expand Harmony Framework Configuration tree, select/expand Graphics Library and configure Graphics Library as shown.



Step 8: Select and Enable USB Host MSD Library as shown :



Step 9: Generate and save the configuration as shown :



It may be needed to close and reopen the modified MPLAB X project to be able to see the new PIC32MX configuration

Congratulations! You just finished the new PIC32MX configuration!

TLS4102 class : Getting started with MPLAB® Harmony Framework

ATTENDEE :
As this lab is meant to show the **easiness** to move an existing application from one PIC32MZ hardware platform to a totally different PIC32MX hardware platform, attendees will most probably not have this PIC32MX hardware platform on their desk.
You can therefore **just build the project** to verify that there is no error : 

PRESENTER :
The presenter will demonstrate that the application, build and execute the same tasks on the PIC32MX platform as on the PIC32MZ platform **without changing a single line of the application SW !!!**

PIC32MX platform setup
For the MEB hardware platform based on PIC32MX, ensure that the jumpers on the UART-to-USB Pictail adapter board have been relocated to the MEB1 position.

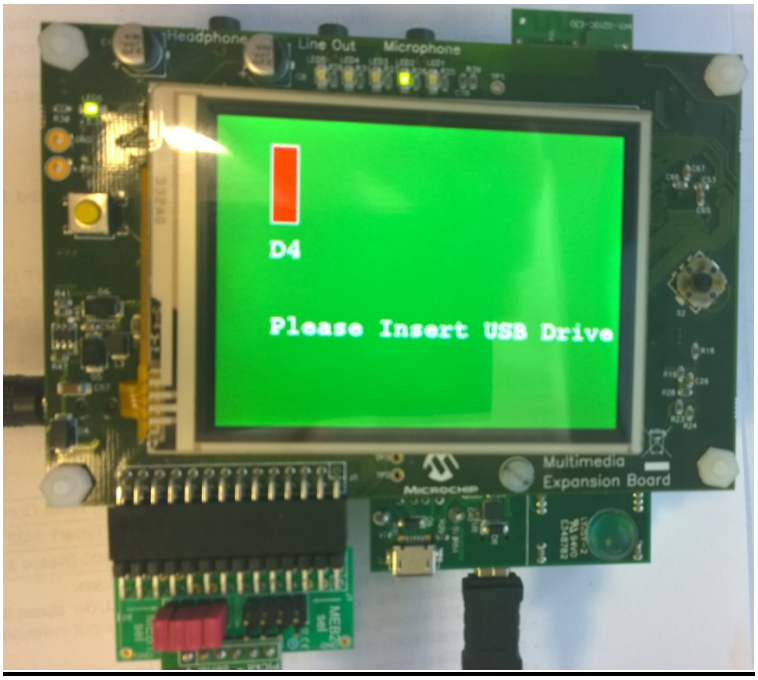
You can now build, program, and run the application : 

When the final application is running and you insert a USB Pen Drive into the PIC32MX Starter Kit a stored message is read out from the Pen Drive and displayed on the MEB TFT display (which even has a different size !) and also transmitted on UART TX. (Pay attention that the COM Port has most probably changed).

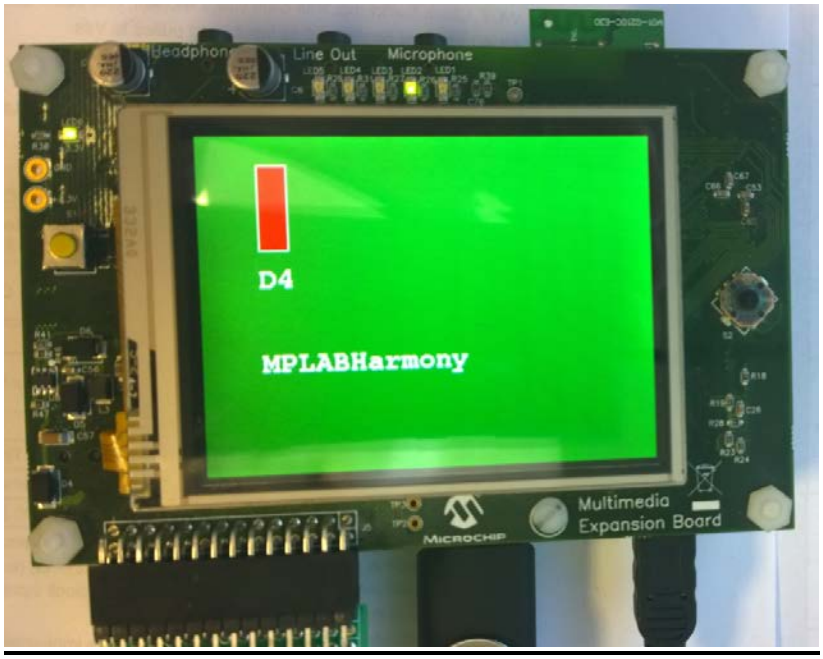
See the next page for expected results displayed on the PIC32MX hardware.

1. Text should be displayed on the MEB display.
2. Text should also be displayed on terminal application.
3. LED continues to blink with status also displayed on the MEB TFT LCD display.

Display *before* USB Pen Drive is inserted into PIC32 USB Starter Kit II



Display *after* USB Pen Drive is inserted into PIC32 USB Starter Kit II



Lab 4 Demo: MPLAB® Harmony and RTOSes

Lab 4 Demo: MPLAB® Harmony and RTOSes

Demo Objectives:

- Overview on how MPLAB Harmony and RTOSes work together in an application
- Gain a brief understanding of how MPLAB Harmony drivers and middleware operate in a multi-threaded pre-emptive environment
- Brief overview of the term Operating System Abstraction Layer (OSAL).

UART Driver Demo

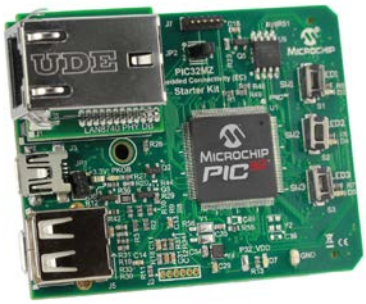
- Two tasks try to access the same hardware UART peripheral to print out an ASCII string. Each tasks prints its own unique string
- Each task will run and try to print its own unique string, when its associated pushbutton switch is .pressed.
- By connecting a USB cable from the starter kit to a PC, and opening an ASCII terminal emulator program (TeraTerm Pro, RealTerm, etc.), the user can see the ASCII strings being correctly printed.

USB Stack Demo

- This demo is a take home but the concept is the same as the UART driver demo, just with a more complex piece of software. This demo shows the complexity of running multiple threads and using the MPLAB Harmony USB stack in a thread safe manner.

Development Boards

DM320006-C - PIC32MZ Embedded Connectivity Starter Kit w/Crypto Engine



- On-board PIC32MZ2048ECM144 with 200 MHz, 2 MB Flash and 512 KB RAM with crypto engine
- Includes 10/100 Fast Ethernet LAN8740 PHY Daughter Board
  - Features Energy Efficient Ethernet (IEEE 802.3az) and Wake-On-LAN functionality
- Integrated debugger/programmer
- USB powered
- 10/100 Ethernet
- CAN 2.0b, Hi-Speed USB 2.0 host/device/dual-role/OTG
- 4 MB SQI Flash
- Can be used with Multimedia Expansion Board II
- Can be used with PIC32 Expansion Board using a PIC32MZ adaptor board.

DM320006 - PIC32MZ Embedded Connectivity Starter Kit

- On-board PIC32MZ2048ECH144: 200 MHz, 2 MB Flash and 512 KB RAM
- Includes 10/100 Fast Ethernet LAN8740 PHY Daughter Board
  - Features Energy Efficient Ethernet (IEEE 802.3az) and Wake-On-LAN functionality
- Integrated debugger/programmer
- USB powered
- 10/100 Ethernet
- CAN 2.0b, HI-Speed USB 2.0 host/device/dual-role/OTG
- 4 MB SQI Flash
- Can be used with Multimedia Expansion Board II
- Can be used with PIC32 Expansion Board using a PIC32MZ adaptor board.

DM320005-2, Multimedia Expansion Board II (MEB II)

- Works with the following kits:
  - PIC32MZ EC Starter Kit w/ Crypto Engine
  - PIC32MZ EC Starter Kit
- 24-bit stereo audio codec
- Integrated 802.11 b/g wireless module
- Low-cost Bluetooth HCI transceiver
- Optional EBI SRAM memory
- 4.3" WQVGA PCAP touch display daughter board
- microSD slot
- mTouch sensing solutions buttons
- Analog temperature sensor
- VGA camera
- PICtail connector