PSoC™ Roadshow Technical Workshop

Day 1 – PSoC™ 4 and ModusToolbox™

Objective: Understand the basic workflow of ModusToolbox™ leveraging low-level peripheral driver APIs, ModusToolbox™ Device Configurator, and CAPSENSE middleware

Prerequisites and Important Information

Installed Software:

- ModusToolbox™ Tools Package v3.0.0

Hardware being used:

- PSoC™ 4100S Plus Prototyping Kit (CY8CKIT-149)

Provided workshop collateral:

- **PSoC Roadshow Workshop Session 1 Lab Guide.pdf** (this document)

- Files to be referenced during workshop
  - **PSoC_4_Code_Snippets.c** – reference file containing blocks of code to be copied into project
  - **game.c / game.h** – additional project files to add game mechanics into workshop project
  - **final_main**.c – reference file containing final main.c implementation

Section 1 – Importing and Exploring a ModusToolbox code example

1. Open **Eclipse IDE for ModusToolbox v3.0**

2. Create a New Application
   - Create new Workspace directory within User directory (example c:\users\username\psoc4_workshop)
   - From Quick Panel select **New Application**, this action will launch the Project Creator
   - Select the board support package: **PSoC™ 4 BSP** -> **CY8CKIT-149**
   - Press **Next,** review available Code Examples
   - Check the template application: **Getting Started -> Hello World**
   - (Optional) Change project name to **MyProject** (or preferred name)
   - Select **Create** to clone the application, create the eclipse project, and import the required BSP files and libraries

3. Review key element of the Eclipse IDE for ModusToolbox
   - Use Quick Panel to start **building** the MyProject application

4. Review mtb_shared folder structure. Some key elements to review are:
   - Library folders with release subfolders, README files, and Documentation folders

5. Review project folder structure. Some key elements to review are:
   - Top level project folder – main.c, Makefile, subfolders
   - README files
   - **deps** – dependency directory for application, including user selected libraries and BSP
   - **libs** – mtb workflow files, make recipe, BSP folder (files managed with ‘make getlibs’)
   - **COMPONENT_CUSTOM_DESIGN_MODUS/TARGET_CY8CKIT-149** - Board Support Package

6. Review **main.c** of MyProject code examples. Key element to notice:
   - Device bring-up and initialization: **cybsp_init()**
   - Configuration of SCB UART using PDL APIs (Init and Enable)
   - Serial printout of text string
   - Main while loop with GPIO toggle and delay function

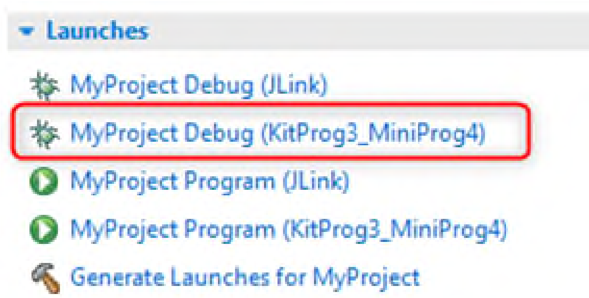
7. Add UART PutString command to clear Serial Terminal Console
   - Locate provided **PSoC_4_Code_Snippets.c** file, and open in Eclipse IDE (drag-and-drop) or preferred editor.
   - Add **code to “clear” serial terminal** to **main.c** file (copy/paste) just before existing PutString function

```
Cy_SCB_UART_PutString(CYBSP_UART_HW, "\x1b[2J\x1b[;H");
```

Section 2 – Debugging with Eclipse IDE for ModusToolbox

1. Open a Serial Terminal within the Eclipse IDE for ModusToolbox
   - Ensure development board is connected to PC using the USB cable
   - Select the Terminal panel (in lower section of IDE)
   - Select the Open a Terminal icon (or press Ctrl-Alt-Shift-T)
     - Choose terminal: **Serial**
     - **Configure** Serial Port (likely the last entry in the list)
     - Baud rate: **115200** (default)
   - Recommended: Relocate the Terminal panel to a new location within the IDE

2. **Flash** application to development board and launch a **debug** connection
   - Ensure the application has finished compiling with no error within the Console
   - Ensure MyProject is selected (the active project within Eclipse)
   - Select the appropriat **MyProject Debug (KitProg3_MiniProg4)** launch action from the Quick Panel



   - Once a debug session has been established, the IDE will switch to the **Debug tab** and an initial breakpoint at main will be set. There will now be an active Debug toolbar available.

3. Explore Debugging options with in Eclipse IDE for ModusToolbox
   - Setting **breakpoints** in application, within the main for loop
   - **Step Over** and **Step Into** functions

   - Open Peripherals views, paying attention to:
     - **SCB[3]** (DEBUG UART), initialized in main
     - **GPIO -> PRT[3]** (USER LED), initialized during cybsp_init, and toggled within main loop
   - **Resume** action to run until breakpoints
   - Viewing **variables** and creating **expressions**
   - **Restarting** the target while maintaining debug session
   - **Terminating** a Debug session and returning to Project Explorer

Section 3 – Extending to a Pushbutton controlled LED with Low-Level Drivers

1. Configuring a GPIO input signal for use with generated PDL code

   - Ensure the correct project is selected, and open **Device Configurator** (under BSP Configurators)
   - Review features and panels available within Device Configurator, note existing configurations: SCB UART, CAPSENSE, and USER_LED
   - From the Pins tab enable the USER_BTN signal
     - Use the filter text entry to search for "USER"
     - Locate the CYBSP_USER_BTN resource, enable with check box, and add new macro **SW1**
     - Review Parameter panel and configure as Digital Input
       - Set Drive Mode to **Resistive Pull-Up, Input buffer on**
       - Set Interrupt Trigger Type to **Falling Edge**
   - Review **Code Preview** panel and observe define macros (based on **SW1_**)
   - Generate code by saving the design.modus file (**File -> Save / Ctrl-S**)
   - Exit the Device Configurator (**File -> Exit / Alt-F4**)

2. Register interrupt callback function for GPIO Pushbutton

   - Review PDL documentation, exact code snippet is also available within PSoC_4_Code_Snippets.c

```
cy_stc_sysint_t ButtonIRQ_cfg = { .intrPriority = 3, .intrSrc = SW1_IRQ };
Cy_SysInt_Init( &ButtonIRQ_cfg, Button_Callback );
NVIC_EnableIRQ( SW1_IRQ );
```

   - Initialize and Enable interrupt for GPIO
     - Configuration structure, with priority and source
     - Initialization with callback function
     - Enabling of interrupt source with NVIC controller

   - Create Button callback function, cut/paste **GPIO_Inv_xxxx** function from FOR loop

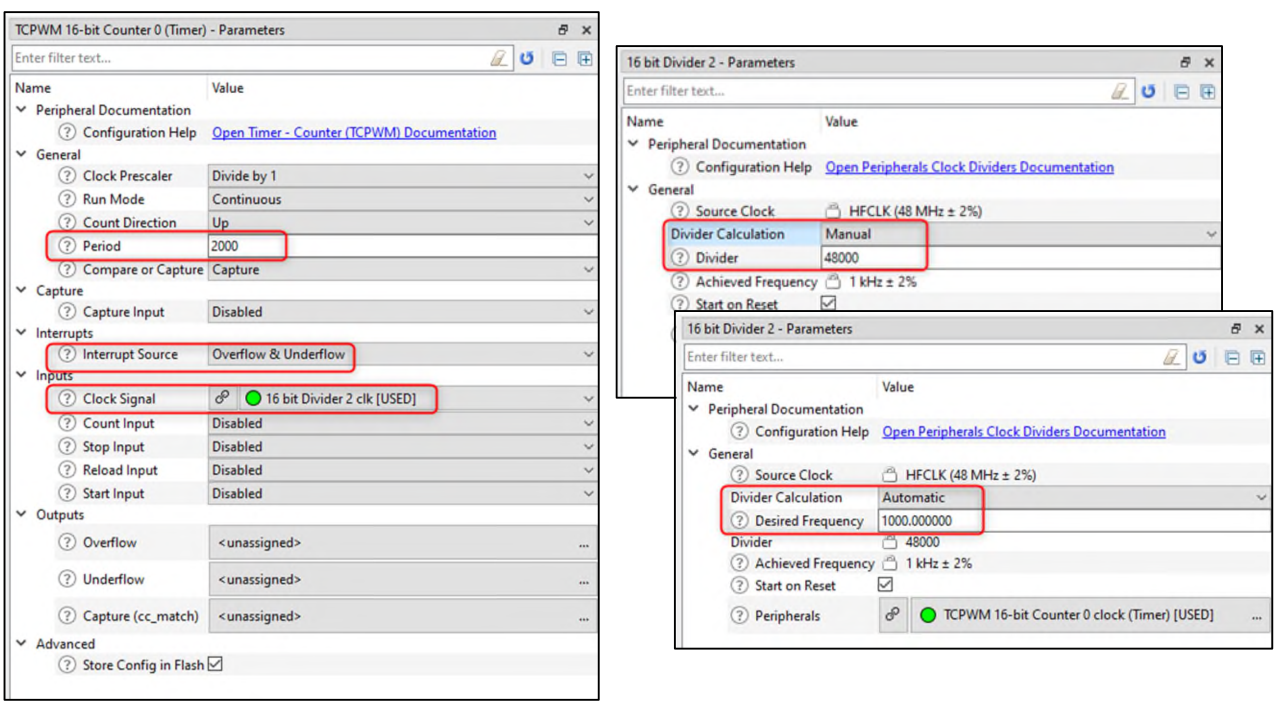
```
void Button_Callback(void)
{
        Cy_GPIO_ClearInterrupt(SW1_PORT, SW1_PIN);
        Cy_GPIO_Inv(CYBSP_USER_LED1_PORT, CYBSP_USER_LED1_PIN);
}
```

3. Compile and Flash application

   - Ensure correct project is selected (the active project within Eclipse)
   - Select the appropriate **MyProject Program (KitProg3_MiniProg4)** launch action from the Quick Panel
   - Observe results in terminal and the LED toggling with each button press.

Section 4 – Add hardware timer with callback function

1. Generate configuration structure for a TCPWM Timer
    - Ensure the correct project is selected, and open **Device Configurator** (under BSP Configurators)
    - From the Peripheral tab enable the **TCPWM 16-bit Counter 0** digital peripheral block
        - Locate the TCPWM 16-bit Counter 0 resource and enable with check box (selecting Counter personality)
        - Provide the macro name **Timer**
        - Specify and configure the appropriate clock settings for the Timer
            - Note the new Task that has been added to the Notice List, and the corresponding icon in the Parameters tab
            - Assign a Clock Signal divider to this peripheral (16 bit Divider 2 clk)
            - Use the link icon to jump to the selected clock divider settings
            - Change the frequency of the clock to **1kHz**
                - Option 1) Divider value of 48000
                - Option 2) Change Divider Calculation to Automatic and Desired Frequency to 1000
            - Return to Timer peripheral setting using the link icon
        - Set **Period** to 2000, this will result in a timer that reached an overflow event every 2.001 seconds
        - Set **Interrupt Source** to Overflow & Underflow



- Review **Code Preview** panel and observe define macros (based on **Timer_**)
- Generate code by saving the design.modus file (**File -> Save / Ctrl-S**)
- Exit the Device Configurator (**File -> Exit / Alt-F4**)

2. Add code to Initialize, Register callback, Enable, and Start Timer
   - Review PDL documentation, exact code snippet is also available within PSoC_4_Code_Snippets.c
   - Similar to the UART initialization and enabling, **Cy_TCPWM_Counter_xxxx** functions are used

```
Cy_TCPWM_Counter_Init(Timer_HW, Timer_NUM, &Timer_config);
Cy_TCPWM_Counter_Enable(Timer_HW, Timer_NUM);
```

   - Similar to the GPIO interrupt callback registering, **Cy_SysInt_xxxx** and **NVIC_EnableIRQ** functions are used

```
cy_stc_sysint_t TimerIRQ_cfg = { .intrPriority = 3, .intrSrc = Timer_IRQ };
Cy_SysInt_Init(&TimerIRQ_cfg, Timer_Callback);
NVIC_EnableIRQ(Timer_IRQ);
```

   - Start the Timer using **Cy_TCPWM_TriggerStart**

```
Cy_TCPWM_TriggerStart(Timer_HW, Timer_MASK);
```

3. Create Timer callback function

```
volatile bool timer_expired = false;
void Timer_Callback(void)
{
        Cy_TCPWM_ClearInterrupt(Timer_HW, Timer_NUM, CY_TCPWM_INT_ON_TC);
        timer_expired = true;
}
```

4. Update main FOR loop, to clear **timer_expired** flag and toggle LED (copy code from Button Callback)

```
for(;;)
{
    if (timer_expired) {
        timer_expired = false;
        Cy_GPIO_Inv(CYBSP_USER_LED1_PORT, CYBSP_USER_LED1_PIN);
    }
}
```

5. Compile and Flash application
   - Ensure correct project is selected (the active project within Eclipse)
   - Select the appropriate **<Project Name> Program (KitProg3_MiniProg4)** launch action from the Quick Panel
   - Observe results in terminal and the LED blinky every 2 seconds

Section 5 – Reviewing CAPSENSE (CSD / CSX) configuration

1. Review CAPSENSE device configuration
   - Ensure the correct project is selected, and open **Device Configurator**
   - From Peripherals tab ensure **System -> CSD (CapSense)** is enabled and selected
   - Review Code Preview panel
     - Most defines here are for use with the CSD Low-Level Drivers, this lab will be using the recommended CAPSENSE Middleware
     - Note the **CYBSP_CSD_HW**
   - Review the Parameters panel
     - Launch **CapSense Configurator** from the Parameters panel

2. Review CAPSENSE Configurator
   - **Basic Tab** with 4 defined widgets supported on the CY8CKIT-149
   - **Advanced tab** and sub-tabs for General, CSD and/or CSX settings, and **Widget Details**
     - **Widget Details** tab with hardware and threshold parameters associated to each widget / signal
   - **Pins Tab**, replicating settings found in the Device Configurator

3. Re-generate code by saving and exiting out of the CAPSENSE Configurator and Device Configurator

Section 6 – Initializing and Configuring CASPSENSE based on generated contexts

1. Modify main.c to include required (and recommended) header file, code can be copied from PSoC_4_Code_Snippets.c

   ```
   #include "cycfg_capsense.h"
   ```

2. **Build** the project, to pick up the included header files

3. Initialize CAPSENSE, referencing same code from API documentation
   - Open CAPSENSE Middleware Documentation
   - Navigate to: **API Reference -> High-level functions -> Cy_CapSense_Init**
   - Review **Functional Usage** section, copying code sections into main.c file
     - Block of Initialization Code *(Place with main function)*
     - ISR Config structure for PSoC 4 Fourth Gen *(Place above init code)*
     - CapSense interrupt handler *(Place above main function)*
   - Update interrupt handler to pass correct CapSense_HW define
     - **CYBSP_CSD_HW** *(from Device Configurator)*

Section 7 – Scanning and processing touch events with CAPSENSE middleware

1. Review available code examples, referenced in CAPSENSE middleware Quick Start Guide
   - Code used in this workshop was derived from PSoC 6 Code Example

2. Within the FOR loop add code that will:
   - Check is CAPSENSE is not currently busy (ongoing scanning)
   - If not busy, will process any scanned data and return a status
   - If successful, will then call a function to process and detected touch events
   - Begin the next scan to complete the loop

   The following code can be copied from the PSoC_4_Code_Snippets.c file and pasted within the main FOR loop:

```
/* Scan and Process CAPSENSE widgets */
if (CY_CAPSENSE_NOT_BUSY == Cy_CapSense_IsBusy(&cy_capsense_context)) {
        if (CY_CAPSENSE_STATUS_SUCCESS == Cy_CapSense_ProcessAllWidgets(&cy_capsense_context) ) {
                process_touch();
        }
        Cy_CapSense_ScanAllWidgets(&cy_capsense_context);
}
```

3. Each CASENSE touch event will correspond to controlling an LED. The GPIOs connected to the LEDs need to be enabled within the **Device Configurator**.
   - Using Device Configurator configure the following Pins and **Strong Drive, Input buffer on**
     - P5[2] – CYBSP_LED_BTN0
     - P5[5] – CYBSP_LED_BTN1
     - P5[7] – CYBSP_LED_BTN2

4. Add process_touch code to respond to CAPSENSE touch events
   - Copy reference code from PSoC_4_Code_Snippets.c file (process_touch function)
     - This function includes code only for Button 0
     - Carefully replicate code and edit to support Button 1 & 2
       - button0 -> button1 / button2
       - BTN0 -> BTN1 / BTN2
   - Create function prototype above main function

     ```
     void process_touch(void);
     ```

5. Compile and Flash application
   - Ensure correct project is selected (the active project within Eclipse)
   - Select the appropriate **<Project Name> Program (KitProg3_MiniProg4)** launch action from the Quick Panel
   - Observe results in terminal and the LED blinky every 2 seconds, while CAPSENSE touch pads toggle corresponding LEDs

Section 8 – Add game logic and random LED selection

1. Remove toggling of USER_LED
   - Remove Cy_GPIO_Inv(…) from Button_Callback function
   - Remove Cy_GPIO_Inv(…) from main FOR loop (after timer expire check)

2. Define "Game Over" conditions and add print outs and enters Sleep mode
   - After timer_expires, add check if any **CYSBP_LED_BTNx** is currently ON using **Cy_GPIO_Read(…)**
     - o Code can be copied from PSoC_4_Code_Snippets.c file
     - o If true, print out "Too Slow" using **Cy_SCB_UART_PutString(…)** and enter sleep using **Cy_SysPm_CpuEnterSleep();**

   - Replace turning ON each LED_BTNx with function that prints our "Wrong Button" and enters sleep. Example:

```
if (Cy_GPIO_Read(CYBSP_LED_BTN2_PORT, CYBSP_LED_BTN2_NUM) == CYBSP_LED_STATE_ON) {
        Cy_GPIO_Write(CYBSP_LED_BTN2_PORT, CYBSP_LED_BTN2_NUM, CYBSP_LED_STATE_OFF);
} else  {
        Cy_SCB_UART_PutString(CYBSP_UART_HW, "Wrong Button\r\n");
        Cy_SysPm_CpuEnterSleep();
}
```

3. Turn ON random LED_BTNx using True Random Number Generator Crypto IP
   - Create variable to store random number within main function

```
        uint32_t rndNum = 0;
```

   - Initialize Crypto IP block (refer to PDL documentation for more details)

```
        Cy_Crypto_Enable(CRYPTO);
```

   - If timer expires AND game is not over (due to LEDs still being on), generate random number. This is the ELSE condition after checking any LED is still ON

```
        Cy_Crypto_Trng(CRYPTO, 32UL, &rndNum);
```

   - Add conditional statement to turn on LED_BTNx based on random number. Code can be copied from the PSoC_4_Code_Snippets.c file.

```
if (rndNum%3 == 0) {
        Cy_GPIO_Write(CYBSP_LED_BTN0_PORT, CYBSP_LED_BTN0_NUM, CYBSP_LED_STATE_ON);
} else if (rndNum%3 == 1) {
        Cy_GPIO_Write(CYBSP_LED_BTN1_PORT, CYBSP_LED_BTN1_NUM, CYBSP_LED_STATE_ON);
} else {
        Cy_GPIO_Write(CYBSP_LED_BTN2_PORT, CYBSP_LED_BTN2_NUM, CYBSP_LED_STATE_ON);

}
```

Section 9 – Low Power APIs and callback functions

1. Review PDL documentation for System Power Management (SysPm) APIs
   - Code used in this workshop was derived from PSoC 4 Power Modes code example and PDL documentation

2. Create declaration of SysPm callback structure (this should be a global variable)
   - Copy / Paste block of code from PSoC_4_Code_Snippets.c
     - Function prototype for **Sleep_Callback**
     - Declaration of callback parameters: **callbackParams**
     - Declaration of callback structure: **sleep_cb**

```
cy_stc_syspm_callback_t sleep_cb    =
{
   &Sleep_Callback,    /* Callback function */
   CY_SYSPM_SLEEP,     /* Callback type */
   0,                  /* Skip mode */
   &callbackParams,    /* Callback params */
   NULL, NULL,         /* For internal usage */
};
```

3. Register Callback
   - Within main function, the callback structure is registered using **Cy_SysPm_RegisterCallback(…)**

4. Add callback function
   - Copy / Paste **Sleep_Callback** function from PSoC_4_Code_Snippets.c file. This function can be added to the end of the main.c file.
   - Review code within case statement
     - CY_SYSPM_BEFORE_TRANSITION
       - Turn off all LEDs (LED_BTNx and USER_LED)
       - Stop hardware timer
     - CY_SYSPM_AFTER_TRANSITION
       - Turn on USER_LED
       - Restart hardware timer

5. Compile and Flash application
   - Ensure correct project is selected (the active project within Eclipse)
   - Select the appropriate **<Project Name> Program (KitProg3_MiniProg4)** launch action from the Quick Panel
   - Observe results in terminal and on board
     - A random LED will be turned on, this associated CAPSENSE touch pad must be pressed before the timer
     - If a wrong pad is touched or the LED is not cleared in time, the device enters a low-power state
     - Pressing the SW1, causes a system interrupt. This wakes the device and the game resets

Section 10 – Gamification (making it a challenge)

1. Add additional source and header files
    - Locate provided **game.c** / **game.h** files.
    - Drag-and-Drop files into Eclipse IDE's Project Explorer view (into **MyProject** folder)
    - Confirm that files will be "**Copied**" into project

2. Explore included code
    - #define's
    - game_init
        - Initialization of GPIO pins, done in place of using Device Configurator
        - Resets the score and timer period
    - game_advance
        - Increments score when called
        - If a level threshold is reached, the period of the timer is decreased
    - game_over
        - Prints out the final score
        - Resets the level indicator LEDs
        - Wait to confirm there are no UART or CAPSENSE scanning functions ongoing, this is helpful for a clean power mode transition
    - game_reset
        - Resets the score and timer period

3. Integrate gamification functions
    - Initial game just prior to the FOR loop within main
        - Add **game_init();**
    - Advance game score and level difficulty when timer expires with all LEDs cleared
        - Add **game_advance();**
    - End game when either wrong button is pressed, or timer expires with LEDs not cleared
        - Add **game_over();** (there will be four instances)
    - Reset the game state when exiting Low-Power Sleep mode (part of the Sleep_Callback function)
        - Add **game_reset();**

4. Compile and Flash application
    - Ensure correct project is selected (the active project within Eclipse)
    - Select the appropriate **<Project Name> Program (KitProg3_MiniProg4)** launch action from the Quick Panel
    - Play game! Events and Final score will be printed to serial terminal. Pressing SW1 will restart the game after a game over.

Section 11 – Bonus Content: Breathing LED in Sleep Mode

1. Launch **Device Configurator**
2. In Pin tab, enable **CYBSP_LED5**, this will be our resulting LED output
    - Configure as Strong Drive, Input buffer off
3. In Pin tab, enable **CYBSP_LED6**
    - Default setting (this allows generated code to configure the HSIOM setting required for SMART I/O)
4. In Pin tab, enable **Smart I/O 2** (we are using 2 because it is in the same port as the LED we intend to use)
    - Name BREATHING
5. Launch **Smart I/O Configurator** from Smart I/O 2 Parameter Panel
    - Set I/O 0 to Output
    - Set Chip 0 to Input (Async) / TCPWM 16-bit Counter 2 pwm
    - Set Chip 2 to Input (Async) / TCPWM 16-bit Counter 3 pwm
    - Configure LUT0 to use inputs (Chip 0 / Chip 2 / Chip 2)
    - Set LUT0 to be XNOR (Hex value 0x81) – We are using XNOR due to our LED being Active Low
    - Save and Close
6. Jump to TCPWM 16-bit Counter 2 pwm settings
7. In Peripheral tab, configure **TCPWM 16-bit Counter 2**
    - Enable with PWM personality and name "**PWM2**"
    - Parameters:
        - Clock Prescaler: **Divide by 4**
        - Configure Clock to use "**16 bit Divider 3 clk**"
        - Use default **Period** and **Compare**
8. In Peripheral tab, configure **TCPWM 16-bit Counter 3**
    - Enable with PWM personality and name "**PWM3**"
    - Parameters:
        - Clock Prescaler: **Divide by 4**
        - Configure Clock to use "**16 bit Divider 3 clk**" (same as PWM2)
        - Set **Period** to **32708** (reducing by 60)
        - Set **Compare** to **16354** (reducing by 30)
9. Save and Close **Device Configurator**
10. Refer to PSoC_4_Code_Snippets.c for code to Initialize and Enable Breathing LED (Smart I/O and PWMs)
11. Refer to PSoC_4_Code_Snippets.c for code to Start and Stop the PWM signals within **Sleep_Callback**
12. Compile and Flash application
    - Went device enters Sleep, a breathing LED will be driven on LED5 (with no CPU intervention)