TB3290

MPLAB Harmony v3 Synchronous Drivers and Their Usage in FreeRTOS-Based Applications

Introduction

MPLAB® Harmony v3 allows users to configure the MPLAB Harmony v3 drivers in one of the following two operating modes: Synchronous or Asynchronous. The Asynchronous drivers support a non-blocking implementation model for the data transfer operations, and the Synchronous drivers support a blocking implementation model. Asynchronous drivers can be used in both Real Time Operating System (RTOS) and non-RTOS based environments while the synchronous drivers are suitable for RTOS-based environments. Synchronous drivers are designed to adhere to the blocking need of applications using RTOS.

This document describes using MPLAB Harmony v3 synchronous drivers with FreeRTOS-based applications.

1. Description

A typical design model for a microcontroller-based embedded application is to factor the application functionality into multiple tasks. These tasks are run cooperatively in a super loop (`while(1)` loop) in the `main` function.

Each application task performs a small portion of its functionality and allows the control to move to the other tasks. These tasks will use hardware features (For example, reading/writing to peripherals, such as I^2C, USART, SPI) to implement portions of the work. For the application to work correctly, the peripheral drivers used by these tasks need to be implemented in a non-blocking manner.

The user need to consider the following application, implemented using the cooperative multitasking model.

Problem Statement: The application reads the current room temperature from a temperature sensor. The temperature reading is displayed on a serial console periodically every second. Further, the application writes the temperature readings to the EEPROM. When a character is entered on the console, the last five written temperature values are read from the EEPROM and displayed on the console.

The application is divided into two tasks, the Sensor task and the EEPROM task, and each running their own state machines. The Sensor task and the EEPROM tasks are called from the `SYS_Tasks` routine which is run in a `while(1)` loop. The user triggers the read of the last five stored values in the EEPROM by a user input (keypress on the keyboard) through an asynchronous USART read complete event.

Figure 1-1. Application Design

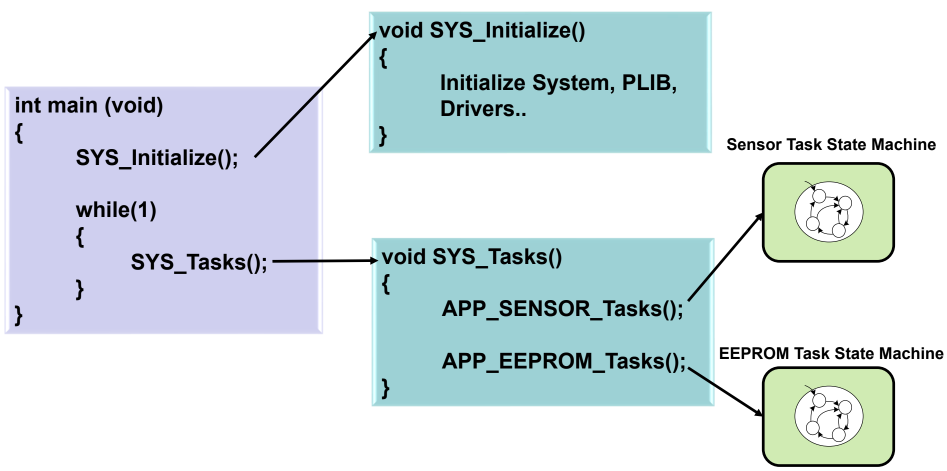
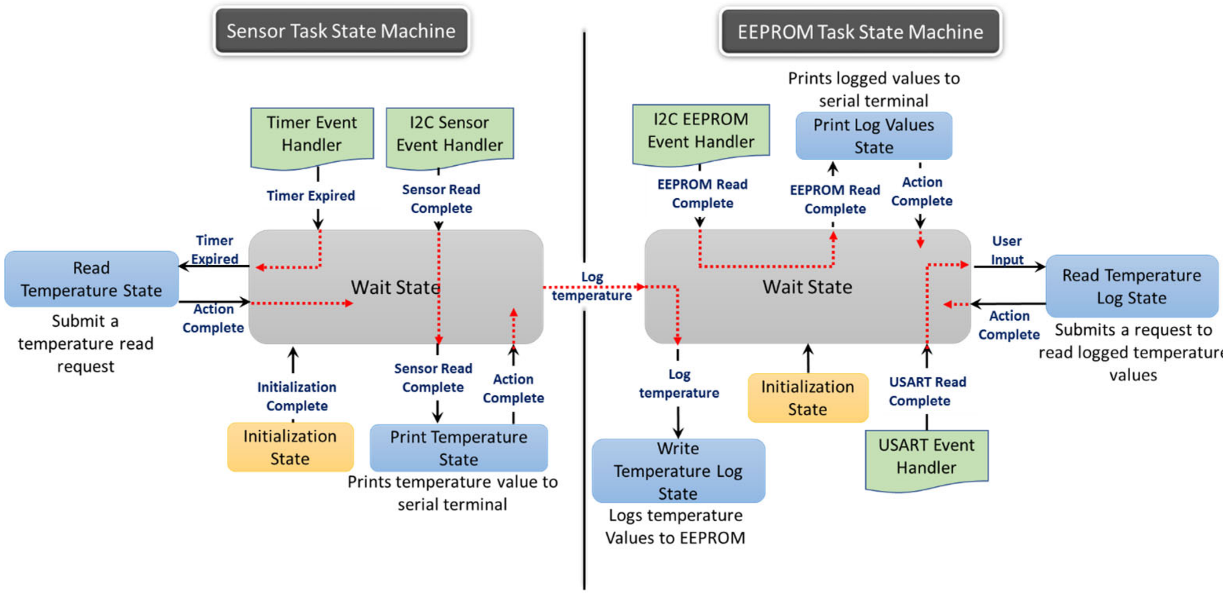


Figure 1-2. Sensor and EEPROM Task State Machine



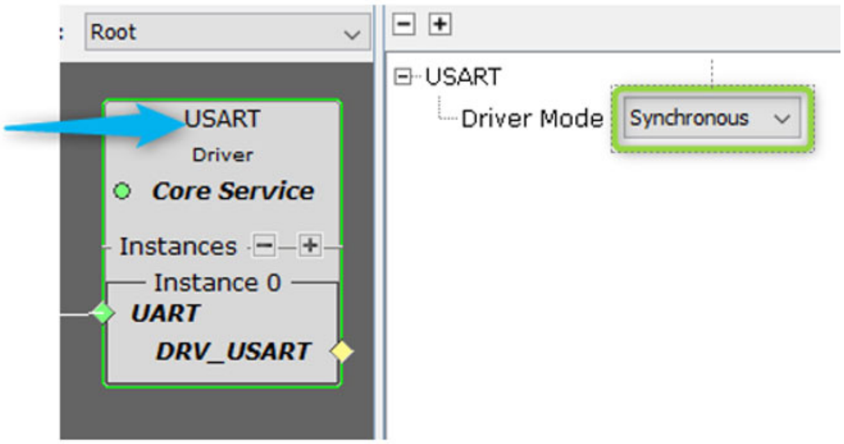
The above state machine based (non-RTOS) application design can be implemented using the asynchronous mode of the MPLAB Harmony v3 drivers.

The cooperative multitasking application design model works well in many situations, but has limitations and faces implementation challenges when the application being designed is large and feature rich constituting multiple sub tasks. This design model faces implementation challenges when an existing application is scaled or extended as the tasks rely on each other regularly giving up the CPU. Also, there are specific situations when a task cannot give up the CPU to other tasks due to its inherent blocking implementation. For example, the file system style read and write functions block and do not return until the entire transfer has completed. In such situations, the application designer can use a Real Time Operating System to perform multitasking and simultaneously allow the use of blocking driver function calls.

2. Configuration

In the MPLAB Harmony v3 Configurator (MHC) project graph, click on the driver block and configure Synchronous mode as shown in the following figure.

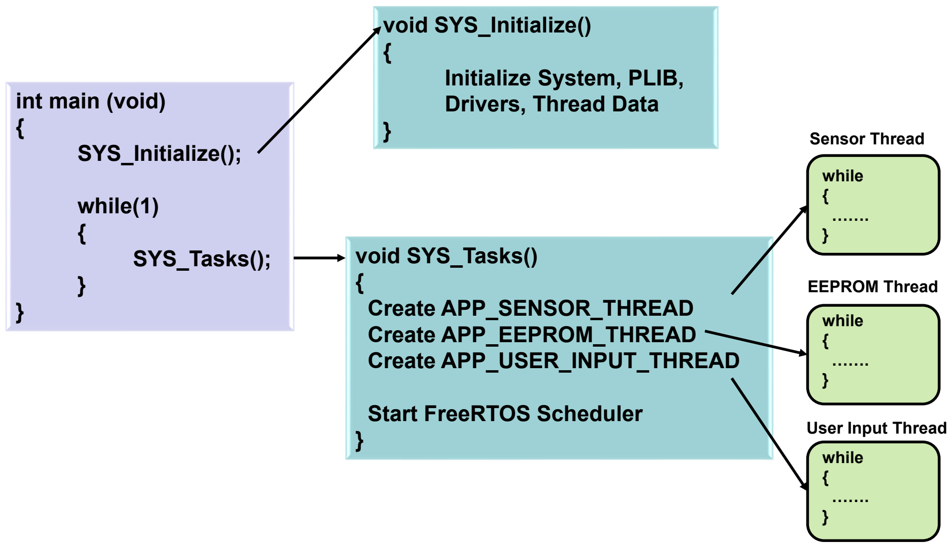
Figure 2-1. Synchronous Mode



3. Implementation

The application design with FreeRTOS using the MPLAB Harmony v3 synchronous driver is shown in the following figure.

Figure 3-1. Application Threads

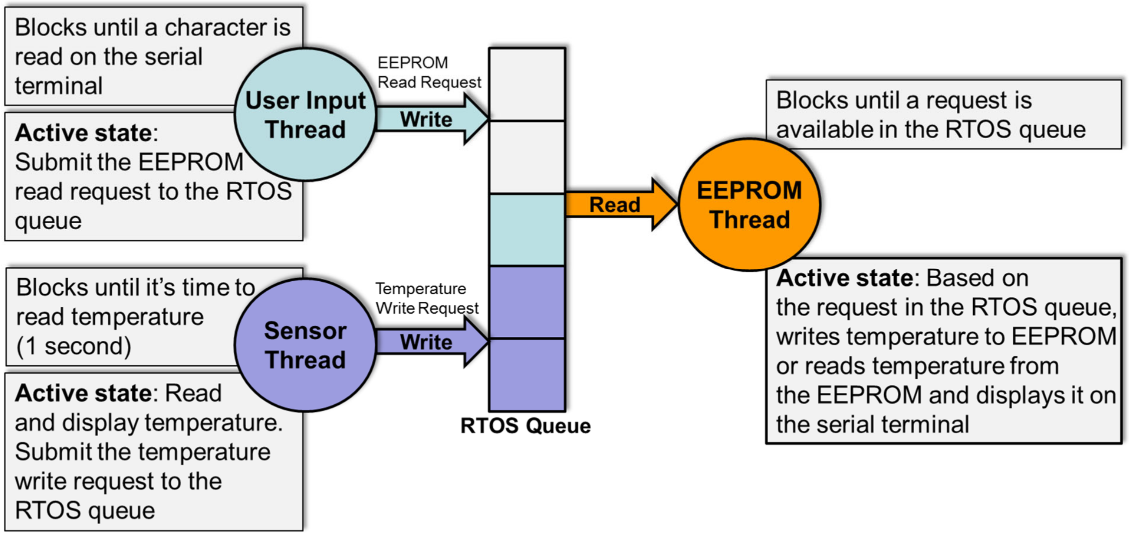


- Sensor Thread: To read and display the temperature periodically.
- EEPROM Thread: To write the temperature values to the EEPROM and display it on the Serial COM-port terminal when requested by the user.
- User Input Thread: To read the character entered on the Serial COM-port terminal to retrieve the last five stored values in the EEPROM.

The Sensor thread, EEPROM thread, and User Input thread run the corresponding application functions in an infinite loop. These threads are created from `SYS_Tasks` routine. Following the creation of these threads, the FreeRTOS scheduler is invoked. The scheduler performs the preemptive scheduling of these threads based on the waiting, ready and running state of each of them. Once the scheduler is invoked, the threads will run based on the default scheduling method (preemptive).

The inter-thread communication between the three threads using the FreeRTOS queue is shown in the following figure.

Figure 3-2. Application Inter-Thread Communication



By default, the sensor thread is blocked and wakes up every time the temperature sampling period gets expired (1 second). Once active, the sensor thread reads the latest room temperature value from the temperature sensor and prints the value on the serial terminal. It also notifies the EEPROM thread through the RTOS queue of the availability of the latest temperature value which needs to be stored in the EEPROM. Once notified, the sensor threads block again for temperature sampling period duration. The following code examples illustrate this with the usage of the FreeRTOS APIs and the MPLAB Harmony v3 driver APIs in Synchronous mode.

```
/* Allow other threads to run until it is time to read temperature */
/* Runs the following code every 1 second. */
vTaskDelay(APP_SENSOR_SAMPLING_RATE_IN_MSEC / portTICK_PERIOD_MS);

/* Submit a blocking I2C write-read request (for temperature). */
/* Calls I2C driver API in synchronous mode  */
if (true == DRV_I2C_WriteReadTransfer(app_sensorData.i2cHandle,
        APP_SENSOR_I2C_SLAVE_ADDR, (void*) &registerAddr, 1,
        (void *) app_sensorData.i2cRxBuffer, 2))
{
    /* ………… Application code ………… */
    /* Use FreeRTOS Queue to notify the temperature write event and temperature
     * value to EEPROM thread. */
    xQueueSend(eventQueue, (void*) &app_sensorData.eventInfo, portMAX_DELAY);

    /* ………… Application code ………… *
    /* Print the temperature value by submitting a blocking USART write request. */
    DRV_USART_WriteBuffer(app_sensorData.usartHandle,
            app_sensorData.usartTxBuffer, strlen);
}
```

By default, the EEPROM thread is in the waiting state for an event to occur. It wakes up when there is an event in the RTOS queue to either write the latest temperature value, or the read last 5 temperature values. Based on the event, the EEPROM thread performs writing or reading, and goes back to the waiting state. The following code examples illustrate this with the usage of FreeRTOS APIs and the MPLAB Harmony v3 driver APIs in synchronous mode.

```
/* Wait for the temperature write request OR EEPROM read request. */
xQueueReceive(eventQueue, &app_eepromData.eventInfo, portMAX_DELAY);

if (app_eepromData.eventInfo.eventType == EVENT_TYPE_TEMP_WRITE_REQ)
{
    /* ………… Application code ………… *
    /* Write temperature to EEPROM */
    if (true == DRV_I2C_WriteTransfer(app_eepromData.i2cHandle,
            APP_EEPROM_I2C_SLAVE_ADDR, (void *) app_eepromData.i2cTxBuffer, 2))
    {
        /* Check if EEPROM has completed the write operation */
        while (false == DRV_I2C_WriteTransfer(app_eepromData.i2cHandle,
                APP_EEPROM_I2C_SLAVE_ADDR, (void *) &dummyData, 1));
```

```
    }

    /* ………… Application code ………… */
}
if (app_eepromData.eventInfo.eventType == EVENT_TYPE_TEMP_READ_REQ)
{
    /* Read the logged temperature values from the EEPROM */
    app_eepromData.i2cTxBuffer[0] = APP_EEPROM_LOG_MEMORY_ADDR;
    if (true == DRV_I2C_WriteReadTransfer(app_eepromData.i2cHandle, \
            APP_EEPROM_I2C_SLAVE_ADDR, app_eepromData.i2cTxBuffer, 1,\
            app_eepromData.i2cRxBuffer, 5))
    {
        /* Print the log values on the terminal */
        APP_EEPROM_PrintTemperature(app_eepromData.i2cRxBuffer,
                app_eepromData.wrIndex);
    }
}
```

By default, the user input thread is blocked to receive a character on the USART receive line. Once a character is received, the user input thread becomes active and submits an EEPROM read request to the EEPROM thread through the RTOS queue to read the last five temperature values stored in the EEPROM. After serving the user input request, the thread goes back to the blocking state to receive another character on the USART receive line. The following code examples illustrate this with the usage of FreeRTOS APIs and the MPLAB Harmony v3 driver APIs in Synchronous mode.

```
    /* Submit a blocking USART read request (user input). Here------> Step #5 */
    if (DRV_USART_ReadBuffer(app_user_inputData.usartHandle, &usartData, 1 ) == true)
    {
        app_user_inputData.eventInfo.eventType = EVENT_TYPE_TEMP_READ_REQ;
        app_user_inputData.eventInfo.eventData = usartData;

        /* Use FreeRTOS queue to notify the EEPROM task to print the logged
    temperature values */
        xQueueSend( eventQueue, &app_user_inputData.eventInfo, portMAX_DELAY );
    }
```

4. References

- Getting Started with MPLAB Harmony v3 drivers on SAM E70/S70/V70/V71 MCUs using FreeRTOS: microchipdeveloper.com/harmony3:same70-getting-started-tm-drivers-freertos
- The Differences Between MPLAB Harmony v3 Synchronous and Asynchronous Drivers and When to Use Them: ww1.microchip.com/downloads/en/DeviceDoc/The-Difference-Between-MPLAB-Harmonyv3-Synchronous-and-Asynchronous-Drivers-and-When-to-Use-DS90003269A.pdf
- MPLAB Harmony v3 Quick Docs provides standalone help pages for users to get started developing applications on Microchip's 32-bit SAM and PIC® MCUs. The offline documentation is available in the "quick_docs" repository downloaded on a PC. Path: <your download location>/quick_docs/docs/index.html. The online pages are available at microchip-mplab-harmony.github.io/quick_docs/.
- For additional information on MPLAB Harmony v3, go to the Microchip web site: www.microchip.com/mplab/mplab-harmony and microchipdeveloper.com/harmony3:start

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