# RTES ECEN-5623

# Project Report

# Occupant Safety (Airbag control Unit and Seat-Belt Adjustment Unit)

# Submitted by

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# on

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# Introduction

Occupant Safety (Airbag Deployment and Seat Belt Adjustment) aims to prototype two of the main automotive safety features i.e. Airbag Control Unit (ACU) and Seat-Belt Adjustment Unit (SAU). ACU manages the mechanism to inflate the Airbag and the SAU helps hold the occupant in place. A crash is detected via a push button interrupt and releases the semaphore for ACU and SAU. Additionally, a speed and temperature monitoring system is used to assist the SAU.

## System overview:

Our system architecture is designed with two primary modules: the Sensor side and the Actuator side, each serving distinct functions crucial for the overall functionality of the system.

A diagram of a process

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*Fig 1.1 Block diagram of Occupant safety*

On the Sensor side, we have three key modules:

Speed Monitoring: This module is responsible for continuously monitoring the speed of the vehicle. It utilizes sensors or devices capable of accurately measuring vehicle speed and provides real-time data to the system for analysis and decision-making.

Temperature Monitoring: This module is dedicated to monitoring the temperature of the heating element, which is crucial for post-crash operations. It ensures that the filament reaches and maintains the desired temperature range for optimal performance in seat belt pretension.

Crash Detection: This module detects crash events using sensors or switches strategically placed within the vehicle. Upon detecting a crash, it triggers the activation of the appropriate safety mechanisms, such as the airbag deployment and seat belt pretensioners.

On the Actuator side, we have two primary modules:

Heating Element: This module controls the heating element, which is essential for seat belt pretension post-crash. It regulates the temperature of the filament based on inputs received from the temperature monitoring module, ensuring optimal performance during operation.

Seat Belt Pretensioners: This module is responsible for deploying the seat belt pretensioners in response to crash events. It receives signals from the crash detection module and coordinates with the heating element module to ensure timely and effective pretension of the seat belts, thereby enhancing occupant safety.

# Hardware Setup

A circuit board with wires and wires

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Microcontroller as ECU

Accelerometer

Thermocouple

Heating filament

Motor driver

Seat belt pretension motor

Ballon as an Airbag

The above picture depicts the hardware arrangement of components as described in the block diagram. The microcontroller is interfaced with the accelerometer, thermocouple, seat belt pretension motor, and heating filament (resistor) with the help of a motor driver.

# Functional Requirements

Before the Crash:

Speed Monitoring: The system must monitor and compute the vehicle speed using acceleration data obtained from the MPU6050 accelerometer.

Temperature Monitoring: The system must pre-heat the heater resistor and maintain a specified temperature threshold by continuously monitoring the temperature using the temperature sensor.

Crash Detection: The system must be capable of simulating a crash event via a GPIO interrupt generated by a push button, triggering the activation of safety mechanisms.

After the Crash:

Seat-Belt Control Unit: The system must adjust the PWM load value of the seat belt motor to tighten the seat belt post-crash, enhancing occupant safety.

Airbag Deployment: The system must increase the temperature of the heater resistor to facilitate airbag deployment post-crash. It should monitor and maintain the temperature within a specified range for a duration of 20ms following crash detection, ensuring timely and effective deployment of the airbag system.

# Real time requirements

**Service 1 Speed Monitoring:​**

https://www.maxxecu.com/webhelp/settings-configuration-ecu\_logging\_settings.html​

The above link from an ECU-Electronic Control Unit manufacturer states that the data logging can be configured to a rate of 1KHz. We have chosen this to have the latest speed data when a crash happens.​

**Service 2 Speed Monitoring:​**

This service is required in our case as the response time for the heater resistor is too large, as seen in the image here. For this reason, we need to pre-heat the resistor to meet the deadline after a crash happens and we have also scaled the temperature values to simulate the same.​  
 A graph showing the temperature

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**Service 3 Seat-Belt Adjustment:**

 (PDF) ANALYSIS OF PROPERTIES OF OPERATION OF THE SUPPORTING EQUIPMENT FOR THE SEAT BELTS (researchgate.net)

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**Service 4 Airbag Deployment:**

Study regarding the influence of airbag deployment time on the occupant injury level during a frontal vehicle collision (matec-conferences.org)

A diagram of a person in a seat

Description automatically generatedA diagram of a driver's seat

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Before the Crash:

Speed Monitoring: Speed must be monitored every 1ms, with a deadline of 508.21us.

Temperature Monitoring: Temperature must be monitored every 2ms, with a deadline of 1.917ms.

Crash Detection: Crash detection must occur within 3.04us upon activation of the push button interrupt.

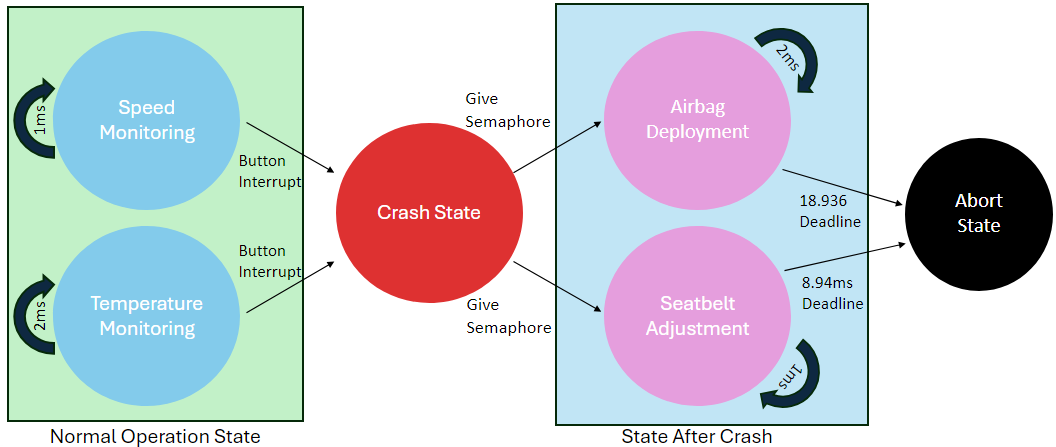
After the Crash:

Seat-Belt Control Unit: The system must adjust the PWM load value for the motor, which is computed based on the speed, within 8.94ms.

Airbag Deployment Unit: The system must increase the temperature of the heater resistor and monitor it for 20ms since crash detection, ensuring timely and effective deployment of the airbag system.

# Functional design

## State diagram:



*Fig 5.1 State diagram*

# In the normal operation state, the system schedules tasks S1 and S2 to monitor speed and temperature, respectively, at regular 1ms and 2ms intervals. Upon pressing the button to trigger a crash event, the system releases semaphores for tasks S3 and S4, responsible for seat-belt control and airbag deployment, respectively. Task S3 adjusts the PWM signal for the motor based on vehicle speed noted during normal operation. Task S4 increases the temperature of the heating element to facilitate airbag inflation. Both tasks S3 and S4 continue their operations until 20ms have elapsed since the crash event. After 20ms, both tasks are aborted, and the system returns to the idle state, ready for further operation.

## Sequence (UML):

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*Fig 5.2 UML Sequence diagram*

Here's a breakdown of the sequence flow based on the provided steps:

1. Initialization of Modules:

Modules like Timer0, I2C, SPI, and PWM are initialized to interface with sensors and actuators.

1. Timer0 Interrupt Handling:

Timer0 is configured to generate interruptions every 1ms.

Upon each interruption, a semaphore is released to trigger the sequencer task.

1. Sequencer Task:

The sequencer task schedules S1 for every 1ms and S2 for every 2ms.

1. Service 1 (S1):

S1 reads acceleration using I2C communication by requesting data from a specific I2C address and register.

1. Service 2 (S2):

S2 reads temperature data from a thermocouple sensor using temp\_readdata() function.

It adjusts the PWM signal to maintain the temperature at 250°C.

1. Crash Detection:

Once a crash is detected, Timer0 interrupts resume.

1. Timer0 Interrupt Handling (After Crash):

Timer0 is configured to generate interruptions every 1ms again.

A semaphore is released upon each interruption to trigger the sequencer task.

1. Sequencer Task (After Crash):

The sequencer task schedules S3 for every 1ms and S4 for every 2ms.

1. Service 3 (S3):

S3 updates PWM signals based on the speed noted before the crash for a certain interval of time.

1. Service 4 (S4):

S4 reads temperature data from a thermocouple sensor using temp\_readdata() function.

It adjusts the PWM signal to maintain the temperature above 270°C.

1. Airbag Deployment:

Once 20ms is reached after the crash, S3 and S4 are aborted, allowing S5 to run.

1. Service 5 (S5):

S5 inflates the airbag and resets the device.

This sequence flow illustrates the sequence of operations performed by different tasks and services in response to events such as timer interruptions and crash detection.

# Real time Analysis

Time profiling of accelerometer input latency:  
 A screenshot of a graph

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Noted around 431.35us required to read data from the accelerometer due to I2C communication.

Time profiling of Temperature sensor input latency:

A screen shot of a graph

Description automatically generated

Noted around 22.585us required to read data from temperature Senor due to SPI communication.

Context Switch Latency:

A screen shot of a graph

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Noted around 60.44us required to do context switch from one task to another.

Button Interrupt Latency:  
   
A screenshot of a graph

Description automatically generated

Noted around 3us required to enter into interrupt handler after push button is pressed.

S1 execution time:  
A screenshot of a graph

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S2 execution time:

A screenshot of a computer

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Computation time for service set after crash (S3, S4):

S3 performs seat belt adjustment for a certain iteration which depends on the speed value before the crash, this entire execution becomes the load for S3. In the worst case scenario where a deadline is not missed the iteration count comes up to 8, and during each iteration executes a fixed number of instructions which runs for 8.576 us. From this we get a WCET of 68.608 us for S3.

Similarly, S2 adjusts the PWM value of the heating element and monitors its temperature for up to 20 ms. Temperature is monitored for about every 2 ms which takes up 87.308 us including input latency and context switch. This can happen for utmost 10 times in 2ms giving WCET as 873.08 us.  
  
Using all the data noted, derived response time for S1, S2, S3 and S4:

Response Timeline for Service Set Before Crash:

Output latencies for these services will be 0 as it won’t involve actuating.

Speed Monitoring Service Response Timeline:

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The above timeline shows input latency while reading 2 bytes of data from the accelerometer via 12c at 400KHz, context switch latency and execution time to compute speed.

Temperature Monitoring Service Response Timeline:

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The above timeline shows input latency while reading 1 byte of data from the accelerometer via SPI at 1MHz, context switch latency and execution time to adjust PWM load.

Response Timeline for Service Set after Crash:

 Seat-Belt Adjustment ServiceA rectangular sign with black text

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The above timeline shows input latency of the button interrupt, context switch latency, execution time to adjust the pretensioner motor and output latency of the actuator(motor).

Airbag Adjustment Service

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The above timeline shows input latency of the button interrupt, context switch latency, execution time required to maintain the temperature of the heater resistor and output latency of the resistor.

# Proof of concept

Selection of Hardware and Software: We chose the Tiva C series microcontroller as the core hardware platform and implemented FreeRTOS as the scheduler to manage task scheduling and execution efficiently.

Integration of Sensors and Actuators: We successfully integrated the necessary sensors, including the accelerometer and temperature sensor, to acquire essential data regarding vehicle speed and post-crash temperature. Additionally, we implemented control mechanisms for the actuators, such as the seat belt pretensioner and heating element, to ensure precise and timely response in critical situations.

A screenshot of a computer

Description automatically generatedImplementation of Crash Detection: To simulate crash detection, we utilized push button interrupts as a trigger mechanism. This allowed us to simulate a crash event and initiate the corresponding safety measures, such as airbag deployment and seat belt pretension, in response to the detected event.

Here, we observe that the scheduler's start time is recorded at the beginning of the program execution. To streamline the logging process and avoid unnecessary data printing, we have selectively included logs only after a crash event occurs. During normal operation, sensor readings are not printed continuously. Instead, logs are generated specifically when the temperature is read every 2ms after a crash event.

Upon detecting a crash, we observe the successful signaling of the seat belt pretensioner after 7ms relative to the crash's start time, noted at 1333ms. Throughout this period, the temperature is maintained at approximately 272°C, meeting the required threshold for airbag deployment.

Continuing the monitoring process for the specified 20ms duration, we confirm the successful completion of the temperature maintenance, indicated by corresponding logs. Finally, the completion message for airbag actuation is received at 108ms post-crash, marking the successful execution of the safety protocol.

# Verification process

# The verification process for our Occupant Safety Project involved several meticulous steps to ensure the functionality, reliability, and compatibility of our prototype. Below is an outline of the verification methods employed:

## Prototype Verification with Arduino UNO: Initially, our project prototype was rigorously verified using Arduino UNO. Arduino UNO was chosen for its extensive library support, abundant examples, and user-friendly programming interface. This platform allowed for seamless verification and understanding of sensor functionalities, streamlining testing and troubleshooting processes.

## Modular Integration: We adopted a modular integration approach, where each project component was individually tested and verified before integration. This method ensured that each component functioned correctly before being integrated into the overall system. Modular integration facilitated efficient debugging and problem isolation, minimizing potential system-wide issues.

## Utilization of UART Logs and LED Indications: During the verification process, UART logs and LED indications served as crucial diagnostic tools. UART logs provided real-time feedback and data logging, enabling detailed analysis of system behavior. LED indicators were employed to provide visual cues for system status, aiding in the identification of any anomalies or errors during testing.

## Profiling with Oscilloscope and TIVA GPIO Pins: System profiling was conducted using an oscilloscope and TIVA GPIO pins. This involved monitoring electrical signals and waveforms generated by the system components to assess performance and timing. Analysis with the oscilloscope and GPIO pins allowed for the identification and resolution of any deviations or inconsistencies in system operation.

## Demo Setup: A meticulously arranged demo setup was prepared to showcase the functionality and performance of our project. The setup simulated real-world scenarios, ensuring all connections and peripherals were appropriately configured.

# Conclusion and Future scope

In conclusion, this project has provided us with a valuable opportunity to develop a prototype aimed at addressing a significant real-world problem concerning occupant safety. Throughout the project, we have gained insights into profiling services, input latency, and execution time, underscoring the critical importance of sensor and actuator response times in ensuring the efficacy of safety mechanisms.

Looking ahead, the future scope of this project involves exploring avenues to integrate more responsive sensors and actuators, thereby enhancing the system's overall performance. Additionally, we aim to refine our understanding by altering the FreeRTOS scheduler clock to achieve more precise timing, enabling finer control over safety feature behavior. By leveraging additional data and insights, we endeavor to further improve the system's response and precision, thereby advancing the cause of occupant safety in automotive applications.

# References

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# Appendix

## Code

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/\*\*

 \* @file main.c

 \* @brief Occupant safety

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

// Include necessary header files

#define TARGET\_IS\_TM4C123\_RA1

#include <stdbool.h>

#include <stdint.h>

#include "inc/hw\_memmap.h"

#include "inc/hw\_types.h"

#include "inc/hw\_ints.h"

#include "driverlib/gpio.h"

#include "driverlib/pin\_map.h"

#include "driverlib/rom.h"

#include "driverlib/sysctl.h"

#include "driverlib/uart.h"

#include "driverlib/timer.h"

#include "driverlib/pwm.h"

#include "utils/uartstdio.h"

#include "FreeRTOS.h"

#include "task.h"

#include "queue.h"

#include "semphr.h"

#include "accelerometer.h"

#include "temperature\_sensor.h"

#include "button\_interrupt.h"

#include "pwm\_control.h"

// Define constants and variables

#define ACC\_SCALING (2048)

#define SCALE (3)

#define SAM\_DEADLINE (10)

#define ABD\_DEADLINE (20)

#define SEAT\_TIGHT\_ITER (3)

#define SPEED\_OFFSET (4)

#define ACC\_OFFSET (5);

// Function prototypes

static void service1(void \*params);

static void service2(void \*params);

static void service3(void \*params);

static void service4(void \*params);

static void service5(void \*params);

static void Sequencer\_thread(void \*params);

// Semaphore handles

xSemaphoreHandle semSched, semS1, semS2, semS3, semS4, semS5;

// Abort flags

volatile bool abortS1 = false, abortS2 = false, abortS3 = false, abortS4 = false;

// Timing parameters

volatile uint32\_t T1 = 1 \* SCALE;

volatile uint32\_t T2 = 2 \* SCALE;

volatile uint32\_t T3 = 20 \* SCALE;

volatile uint32\_t T4 = 20 \* SCALE;

volatile uint32\_t event\_start = 0;

volatile uint32\_t speed = 0;

#ifdef DEBUG

void

error(char \*pcFilename, uint32\_t ui32Line)

{

}

#endif

// Stack overflow hook

void vApplicationStackOverflowHook(xTaskHandle \*pxTask, char \*pcTaskName)

{

    // Handle stack overflow

    while (1)

    {

    }

}

/\*\*

 \* @func    ConfigureUART

 \* @brief   Configures UART0 for communication

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM Example

 \*/

void ConfigureUART(void)

{

    // Enable the GPIO peripheral for Port A

    ROM\_SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOA);

    // Enable the UART peripheral

    ROM\_SysCtlPeripheralEnable(SYSCTL\_PERIPH\_UART0);

    // Configure PA0 as the UART RX pin

    ROM\_GPIOPinConfigure(GPIO\_PA0\_U0RX);

    // Configure PA1 as the UART TX pin

    ROM\_GPIOPinConfigure(GPIO\_PA1\_U0TX);

    // Set PA0 and PA1 as UART pins

    ROM\_GPIOPinTypeUART(GPIO\_PORTA\_BASE, GPIO\_PIN\_0 | GPIO\_PIN\_1);

    // Set the clock source for UART0 to the precision internal oscillator (PIOSC)

    UARTClockSourceSet(UART0\_BASE, UART\_CLOCK\_PIOSC);

    // Configure UART0 with standard I/O settings

    // Parameters: 0 for the UART instance, baud rate of 230400, and system clock frequency of 16,000,000

    UARTStdioConfig(0, 230400, 16000000);

}

/\*\*

 \* @func    timer0\_init

 \* @brief   Initializes Timer0 for periodic operation

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM Example

 \*/

void timer0\_init(){

    // Enable Timer0 peripheral

    ROM\_SysCtlPeripheralEnable(SYSCTL\_PERIPH\_TIMER0);

    // Configure Timer0A to run in periodic mode at 1000Hz

    ROM\_TimerConfigure(TIMER0\_BASE, TIMER\_CFG\_PERIODIC);

    ROM\_TimerLoadSet(TIMER0\_BASE, TIMER\_A, ROM\_SysCtlClockGet() / 1000);

    // Enable Timer0A interrupt

    ROM\_IntEnable(INT\_TIMER0A);

    ROM\_TimerIntEnable(TIMER0\_BASE, TIMER\_TIMA\_TIMEOUT);

    // Enable Timer0A

    ROM\_TimerEnable(TIMER0\_BASE, TIMER\_A);

}

/\*\*

 \* @func    Timer0IntHandler

 \* @brief   Interrupt handler for Timer0

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM Datasheet - Timer0 Section

 \*/

void Timer0IntHandler(void)

{

    // Clear the interrupt flag for Timer A timeout

    ROM\_TimerIntClear(TIMER0\_BASE, TIMER\_TIMA\_TIMEOUT);

    // Release the semaphore to signal the sequencer

    xSemaphoreGive(semSched);

}

/\*\*

 \* @func    ButtonHandler

 \* @brief   Interrupt handler for button press event

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM Example

 \*/

void ButtonHandler(void)

{

    // Disable interrupt for GPIO pin 4 on Port F

    GPIOIntDisable(GPIO\_PORTF\_BASE, GPIO\_PIN\_4);

    // Write GPIO pin 1 on Port F to HIGH

    GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_1, GPIO\_PIN\_1);

    // Set abort flags for services 1 and 2

    abortS1 = true;

    abortS2 = true;

    // Release semaphores for services 3, 4, and 5

    xSemaphoreGive(semS3);

    xSemaphoreGive(semS4);

    xSemaphoreGive(semS5);

    // Record the event start time

    event\_start = xTaskGetTickCount();

}

/\*\*

 \* @func    Sequencer\_thread

 \* @brief   Task for managing the sequencing of events

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void Sequencer\_thread(void \*params)

{

    // Static variable to keep track of scheduler count

    static volatile uint32\_t schedCnt = 0;

    // Print a message indicating that the sequencer has started

    UARTprintf("Sequencer Started at %u msec\n", xTaskGetTickCount());

    // Infinite loop for sequencer operation

    while (1)

    {

        // Wait indefinitely for the scheduler semaphore

        xSemaphoreTake(semSched, portMAX\_DELAY);

        // Increment the scheduler count

        schedCnt++;

        // Check if it's time to release semaphore S1

        if (schedCnt % T1 == 0 && !abortS1)

        {

            xSemaphoreGive(semS1);

        }

        // Check if it's time to release semaphore S2

        if (schedCnt % T2 == 0 && !abortS2)

        {

            xSemaphoreGive(semS2);

        }

        // Check if it's time to release semaphore S3 (abort condition)

        if (schedCnt % T1 == 0 && abortS1)

        {

            xSemaphoreGive(semS3);

        }

        // Check if it's time to release semaphore S4 (abort condition)

        if (schedCnt % T2 == 0 && abortS2)

        {

            xSemaphoreGive(semS4);

        }

    }

}

/\*\*

 \* @func    service1

 \* @brief   Task for processing data from accelerometer

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void service1(void \*params)

{

    // Static variables to store accelerometer and gyroscope readings

    static volatile uint16\_t acc\_xh = 0, acc\_xl = 0;

    static volatile uint16\_t gyro\_xh = 0, gyro\_xl = 0;

    // Loop until the abortS1 flag is set

    while (!abortS1)

    {

        // Wait indefinitely for semaphore S1

        xSemaphoreTake(semS1, portMAX\_DELAY);

        // Turn on an LED (assuming GPIO\_PIN\_3 is connected to an LED)

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_3, GPIO\_PIN\_3);

        // Read accelerometer data

        acc\_xh = (read\_from\_accelerometer(I2C0\_BASE, 0x68, 0x3B) << 8);

        acc\_xl = read\_from\_accelerometer(I2C0\_BASE, 0x68, 0x3C);

        acc\_xh |= acc\_xl;

        // Read gyroscope data

        gyro\_xh = (read\_from\_accelerometer(I2C0\_BASE, 0x68, 0x43) << 8);

        gyro\_xl = read\_from\_accelerometer(I2C0\_BASE, 0x68, 0x44);

        // Processing accelerometer data

        acc\_xh /= ACC\_SCALING - ACC\_OFFSET;

        speed += acc\_xh;

        // Turn off the LED

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_3, 0);

        // Print accelerometer data

        //UARTprintf("A: %d\n", acc\_xh);

    }

    // Print a message indicating that Service 1 is exiting

    //UARTprintf("S1 exit\n");

    // Delete the task

    vTaskDelete(NULL);

}

/\*\*

 \* @func    service2

 \* @brief   Task for processing data from temperature sensor

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void service2(void \*params)

{

    // Variable to store temperature reading

    uint16\_t temp;

    // Initial duty cycle for PWM

    uint16\_t duty\_cycle = (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 4);

    // Loop until the abortS2 flag is set

    while (!abortS2)

    {

        // Wait indefinitely for semaphore S2

        xSemaphoreTake(semS2, portMAX\_DELAY);

        // Turn on an LED (assuming GPIO\_PIN\_2 is connected to an LED)

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_2, GPIO\_PIN\_2);

        // Read temperature data

        temp = tmp\_readdata() \* 2;

        // Adjust PWM duty cycle based on temperature

        if (temp + TEMP\_OFFSET >= 260)

        {

            duty\_cycle = (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 4);

            PWMPulseWidthSet(

                PWM0\_BASE, PWM\_OUT\_0,

                duty\_cycle);

        }

        else

        {

            duty\_cycle = (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 3);

            PWMPulseWidthSet(PWM0\_BASE, PWM\_OUT\_0,

                             duty\_cycle);

        }

        // Turn off the LED

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_2, 0);

        // Print temperature data

        //UARTprintf("\rT: %d\n", temp);

    }

    // Delete the task

    vTaskDelete(NULL);

}

/\*\*

 \* @func    service3

 \* @brief   Task for managing seat adjustment mechanism

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void service3(void \*params)

{

    // Variable to count iterations

    int itr = 0;

    // Variable to store end time for service 3

    volatile uint32\_t s3\_end\_time = 0;

    // Loop until the abortS3 flag is set

    while (!abortS3)

    {

        // Check if semaphore S3 is taken

        xSemaphoreTake(semS3, portMAX\_DELAY);

        // Adjust PWM pulse width for PWM output 1

        PWMPulseWidthSet(PWM0\_BASE, PWM\_OUT\_1,

                         (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 10) \* 9);

        // Increment iteration count

        itr++;

        // Check if iterations exceed a certain threshold

        if (itr > SEAT\_TIGHT\_ITER)

        {

            // Activate seat tightening mechanism

            GPIOPinWrite(GPIO\_PORTC\_BASE, GPIO\_PIN\_6, 0);

            GPIOPinWrite(GPIO\_PORTC\_BASE, GPIO\_PIN\_7, GPIO\_PIN\_7);

            PWMPulseWidthSet(PWM0\_BASE, PWM\_OUT\_1,

                             (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 10) \* 10);

        }

        // Check if iterations exceed the speed offset

        if (itr > SPEED\_OFFSET + speed)

        {

            // Exit the loop if conditions are met

            break;

        }

    }

    // Disable PWM output for PWM0 output 1

    PWMOutputState(PWM0\_BASE, PWM\_OUT\_1\_BIT, false);

    // Get the end time for service 3

    s3\_end\_time = xTaskGetTickCount();

    // Check if SAM deadline is missed

    if ((s3\_end\_time - event\_start) > SAM\_DEADLINE)

    {

        UARTprintf("SAM deadline missed T: %d S: %d E: %d itr %d\n", s3\_end\_time - event\_start, event\_start, s3\_end\_time, itr);

    }

    else

    {

        UARTprintf("SAM Successful T: %d S: %d E: %d itr %d\n", s3\_end\_time - event\_start, event\_start, s3\_end\_time, itr);

    }

    // Delete the task

    vTaskDelete(NULL);

}

/\*\*

 \* @func    service4

 \* @brief   Task for managing temperature control mechanism

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void service4(void \*params)

{

    // Variable to store temperature reading

    uint16\_t temp;

    // Duty cycle for PWM output

    uint16\_t duty\_cycle = (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 4);

    // Variable to store end time for service 4

    uint32\_t s4\_end\_time = 0;

    // Loop until the abortS4 flag is set

    while (!abortS4)

    {

        // Wait indefinitely for semaphore S4

        xSemaphoreTake(semS4, portMAX\_DELAY);

        // Turn on an LED (assuming GPIO\_PIN\_2 is connected to an LED)

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_2, GPIO\_PIN\_2);

        // Read temperature data

        temp = tmp\_readdata() \* 2;

        // If temperature is above a certain threshold, adjust PWM output

        if (temp + TEMP\_OFFSET >= 285)

        {

            PWMPulseWidthSet(

                PWM0\_BASE,

                PWM\_OUT\_0,

                (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 5) \* 2 - (PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 10));

        }

        else

        {

            PWMPulseWidthSet(

                PWM0\_BASE, PWM\_OUT\_0,

                ((PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0)) / 10) \* 10);

        }

        // Get current time

        s4\_end\_time = xTaskGetTickCount();

        // If deadline is reached, exit loop

        if ((s4\_end\_time - event\_start) >= ABD\_DEADLINE)

        {

            break;

        }

        // Turn off the LED

        GPIOPinWrite(GPIO\_PORTF\_BASE, GPIO\_PIN\_2, 0);

        // Print temperature data and execution time

        UARTprintf("\rT: %d\n", temp);

    }

    // Check if ABD deadline is missed

    if ((s4\_end\_time - event\_start) > ABD\_DEADLINE)

    {

        UARTprintf("ABD deadline missed T: %d S: %d E: %d\n", s4\_end\_time - event\_start, event\_start, s4\_end\_time);

    }

    else

    {

        UARTprintf("ABD Successful T: %d S: %d E: %d\n", s4\_end\_time - event\_start, event\_start, s4\_end\_time);

    }

    // Delete the task

    vTaskDelete(NULL);

}

/\*\*

 \* @func    service5

 \* @brief   Task for deploying airbag

 \* @param   params: Pointer to task parameters (unused)

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Semaphore Management

 \*/

static void service5(void \*params)

{

    // Wait indefinitely for semaphore S5

    xSemaphoreTake(semS5, portMAX\_DELAY);

    // Deploy airbag by writing to servo

    servo\_write(10);

    // Get current time

    uint32\_t end\_time = xTaskGetTickCount();

    // Print message indicating successful airbag deployment along with execution time

    UARTprintf("Air bag deployed T: %d S: %d E: %d\n", end\_time - event\_start, event\_start, end\_time);

    // Delete the task

    vTaskDelete(NULL);

}

/\*\*

 \* @func    main

 \* @brief   Entry point of the program

 \* @param   None

 \* @return  None

 \* @reference   FreeRTOS API Documentation - Task Management

 \*/

void main(void)

{

    // Enable lazy stacking for floating-point instructions

    ROM\_FPULazyStackingEnable();

    // Configure the system clock to use the main oscillator with a 16MHz crystal

    ROM\_SysCtlClockSet(

            SYSCTL\_SYSDIV\_1 | SYSCTL\_USE\_OSC | SYSCTL\_OSC\_MAIN

                    | SYSCTL\_XTAL\_16MHZ);

    // Configure UART communication

    ConfigureUART();

    // Initialize I2C0

    init\_i2c0();

    // Initialize button

    button\_init();

    // Initialize temperature sensor

    tmp\_sensor\_init();

    // Initialize PWM for heating

    heating\_pwm\_init();

    // Initialize PWM for seat control

    seat\_pwm\_init();

    // Initialize servo motor

    servo\_init();

    servo\_write(90);

    // Initialize Timer0 for scheduler

    timer0\_init();

    // Print a welcome message

    UARTprintf("\nRTES Final Project\n\n");

    // Initialize semaphores

    semSched = xSemaphoreCreateMutex();

    semS1 = xSemaphoreCreateMutex();

    semS2 = xSemaphoreCreateMutex();

    semS3 = xSemaphoreCreateMutex();

    semS4 = xSemaphoreCreateMutex();

    semS5 = xSemaphoreCreateMutex();

    // Restrict services to start before the sequencer

    xSemaphoreTake(semS1, portMAX\_DELAY);

    xSemaphoreTake(semS2, portMAX\_DELAY);

    xSemaphoreTake(semS3, portMAX\_DELAY);

    xSemaphoreTake(semS4, portMAX\_DELAY);

    xSemaphoreTake(semS5, portMAX\_DELAY);

    // Create tasks for sequencer and services

    xTaskCreate(Sequencer\_thread, "Sequencer Thread", 128, NULL,

                tskIDLE\_PRIORITY + 6, NULL);

    xTaskCreate(service1, "Service 1", 128, NULL, tskIDLE\_PRIORITY + 4, NULL);

    xTaskCreate(service2, "Service 2", 128, NULL, tskIDLE\_PRIORITY + 3, NULL);

    xTaskCreate(service3, "Service 3", 128, NULL, tskIDLE\_PRIORITY + 5, NULL);

    xTaskCreate(service4, "Service 4", 128, NULL, tskIDLE\_PRIORITY + 4, NULL);

    xTaskCreate(service5, "Service 5", 128, NULL, tskIDLE\_PRIORITY + 3, NULL);

    // Start the FreeRTOS scheduler

    vTaskStartScheduler();

    // Code should never reach here, but keep an infinite loop just in case

    while (1)

        ;

}

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file accelerometer.h

 \* @brief Accelerometer initialization and access APIs

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

#include <stdint.h>

void init\_i2c0(void);

void write\_to\_accelerometer(uint32\_t ui32Base, uint8\_t ui8SlaveAddr,

                            uint8\_t nargs, ...);

uint32\_t read\_from\_accelerometer(uint32\_t ui32Base, uint8\_t ui8SlaveAddr,

                                 uint8\_t reg);

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file accelerometer.c

 \* @brief Accelerometer initialization and access APIs

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

#define TARGET\_IS\_TM4C123\_RA1

#include "accelerometer.h"

#include <stdbool.h>

#include <stdint.h>

#include "inc/hw\_memmap.h"

#include "inc/hw\_types.h"

#include "inc/hw\_ints.h"

#include "inc/hw\_i2c.h"

#include "driverlib/gpio.h"

#include "driverlib/pin\_map.h"

#include "driverlib/rom.h"

#include "driverlib/sysctl.h"

#include "driverlib/i2c.h"

#include "stdarg.h"

/\*\*

 \* @func    init\_i2c0

 \* @brief   Initializes I2C0 peripheral and GPIO port B

 \* @param   None

 \* @return  None

 \* @reference   TivaWare Peripheral Driver Library User's Guide

 \*/

void init\_i2c0(void)

{

    // Enable the I2C0 peripheral and GPIO port B

    ROM\_SysCtlPeripheralEnable(SYSCTL\_PERIPH\_I2C0);

    ROM\_SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOB);

    // Configure the pin muxing for I2C0 functions on port B2 (SCL) and B3 (SDA)

    ROM\_GPIOPinConfigure(GPIO\_PB2\_I2C0SCL);

    ROM\_GPIOPinConfigure(GPIO\_PB3\_I2C0SDA);

    // Set pin types for I2C0

    GPIOPinTypeI2CSCL(GPIO\_PORTB\_BASE, GPIO\_PIN\_2);

    ROM\_GPIOPinTypeI2C(GPIO\_PORTB\_BASE, GPIO\_PIN\_3);

    // Initialize the I2C master with the system clock frequency and enable high-speed mode

    ROM\_I2CMasterInitExpClk(I2C0\_BASE, SysCtlClockGet(), true);

    // Wake up MPU6050 from sleep by writing to its PWR\_MGMT\_1 register

    write\_to\_accelerometer(I2C0\_BASE, 0x68, 2, 0x6B, 0x00);

}

/\*\*

 \* @func    write\_to\_accelerometer

 \* @brief   Writes data to the specified register of the accelerometer via I2C communication

 \* @param   ui32Base: Base address of the I2C module

 \* @param   ui8SlaveAddr: 7-bit slave address of the accelerometer device

 \* @param   nargs: Number of arguments to be written, including the register address

 \* @param   ...: Variable number of arguments to be written, starting with the register address followed by data bytes

 \* @return  None

 \*/

void write\_to\_accelerometer(uint32\_t ui32Base, uint8\_t ui8SlaveAddr,

                            uint8\_t nargs, ...)

{

    // Initialize variable argument list

    va\_list vargs;

    va\_start(vargs, nargs);

    // Extract the register address from the variable arguments

    uint8\_t regAddress = va\_arg(vargs, uint8\_t); // First argument is always the register address

    // Set the slave address and direction to write

    I2CMasterSlaveAddrSet(ui32Base, ui8SlaveAddr, false);

    // Put the register address into the master data register

    I2CMasterDataPut(ui32Base, regAddress);

    // Initiate a burst send start

    I2CMasterControl(ui32Base, I2C\_MASTER\_CMD\_BURST\_SEND\_START);

    // Wait until the I2C master is not busy

    while (I2CMasterBusy(ui32Base))

        ;

    // Loop through the remaining arguments

    uint8\_t i = 0;

    for (i = 1; i < nargs; i++)

    {

        // Put the next data byte into the master data register

        I2CMasterDataPut(ui32Base, va\_arg(vargs, uint8\_t));

        // Determine whether to send a finish or continue command based on the current byte's position

        if (i == nargs - 1)

        {

            I2CMasterControl(ui32Base, I2C\_MASTER\_CMD\_BURST\_SEND\_FINISH);

        }

        else

        {

            I2CMasterControl(ui32Base, I2C\_MASTER\_CMD\_BURST\_SEND\_CONT);

        }

        // Wait until the I2C master is not busy

        while (I2CMasterBusy(ui32Base))

            ;

    }

    // End variable argument list

    va\_end(vargs);

}

/\*\*

 \* @func    read\_from\_accelerometer

 \* @brief   Reads data from the specified register of the accelerometer via I2C communication

 \* @param   ui32Base: Base address of the I2C module

 \* @param   ui8SlaveAddr: 7-bit slave address of the accelerometer device

 \* @param   reg: Register address to read from

 \* @return  Data read from the specified register

 \*/

uint32\_t read\_from\_accelerometer(uint32\_t ui32Base, uint8\_t ui8SlaveAddr,

                                 uint8\_t reg)

{

    // Set the slave address and direction to write the register address

    I2CMasterSlaveAddrSet(ui32Base, ui8SlaveAddr, false);

    // Put the register address into the master data register

    I2CMasterDataPut(ui32Base, reg);

    // Initiate a single send command

    I2CMasterControl(ui32Base, I2C\_MASTER\_CMD\_SINGLE\_SEND);

    // Wait until the I2C master is not busy

    while (I2CMasterBusy(ui32Base))

        ;

    // Set the slave address and direction to read data

    I2CMasterSlaveAddrSet(ui32Base, ui8SlaveAddr, true);

    // Initiate a single receive command

    I2CMasterControl(ui32Base, I2C\_MASTER\_CMD\_SINGLE\_RECEIVE);

    // Wait until the I2C master is not busy

    while (I2CMasterBusy(ui32Base))

        ;

    // Return the data read from the master data register

    return I2CMasterDataGet(ui32Base);

}

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file button\_interrupt.h

 \* @brief Button initialization

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

void button\_init();

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file button\_interrupt.c

 \* @brief Button initialization

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

 #define TARGET\_IS\_TM4C123\_RA1

 #include "button\_interrupt.h"

 #include <stdbool.h>

 #include <stdint.h>

 #include "inc/hw\_memmap.h"

 #include "inc/hw\_types.h"

 #include "inc/hw\_ints.h"

 #include "driverlib/gpio.h"

 #include "driverlib/pin\_map.h"

 #include "driverlib/rom.h"

 #include "driverlib/sysctl.h"

 /\*\*

  \* @func    button\_init

  \* @brief   Initializes the GPIO pins and interrupts for button functionality

  \* @param   None

  \* @return  None

  \* @reference   TM4C123GH6PM examples

  \*/

 void button\_init()

 {

     // Enable the GPIO Port F peripheral

     SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOF);

     // Configure pins 1, 2, and 3 of Port F as GPIO outputs

     GPIOPinTypeGPIOOutput(GPIO\_PORTF\_BASE, GPIO\_PIN\_1);

     GPIOPinTypeGPIOOutput(GPIO\_PORTF\_BASE, GPIO\_PIN\_2);

     GPIOPinTypeGPIOOutput(GPIO\_PORTF\_BASE, GPIO\_PIN\_3);

     // Configure pin 4 of Port F as a GPIO input

     GPIOPinTypeGPIOInput(GPIO\_PORTF\_BASE, GPIO\_PIN\_4);

     // Configure pin 4 of Port F with a weak pull-up resistor

     GPIOPadConfigSet(GPIO\_PORTF\_BASE, GPIO\_PIN\_4, GPIO\_STRENGTH\_2MA, GPIO\_PIN\_TYPE\_STD\_WPU);

     // Enable interrupts for pin 4 of Port F

     GPIOIntEnable(GPIO\_PORTF\_BASE, GPIO\_PIN\_4);

     // Configure pin 4 of Port F to trigger interrupts on falling edge

     GPIOIntTypeSet(GPIO\_PORTF\_BASE, GPIO\_PIN\_4, GPIO\_FALLING\_EDGE);

     // Enable the GPIO Port F interrupt

     ROM\_IntEnable(INT\_GPIOF);

     // Enable the global interrupt flag

     ROM\_IntMasterEnable();

 }

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file pwm\_control.h

 \* @brief PWM initialization and control API's

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

void heating\_pwm\_init();

void seat\_pwm\_init();

void servo\_init();

void servo\_write(float deg);

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file pwm\_control.c

 \* @brief PWM initialization and control API's

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

#define TARGET\_IS\_TM4C123\_RA1

#include "pwm\_control.h"

#include <stdbool.h>

#include <stdint.h>

#include "inc/hw\_memmap.h"

#include "inc/hw\_types.h"

#include "inc/hw\_ints.h"

#include "driverlib/gpio.h"

#include "driverlib/pin\_map.h"

#include "driverlib/rom.h"

#include "driverlib/sysctl.h"

#include "driverlib/pwm.h"

/\*\*

 \* @func    heating\_pwm\_init

 \* @brief   Initializes PWM for heating control

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM examples

 \*/

void heating\_pwm\_init()

{

    // Set the PWM clock to run at the system clock divided by 1

    SysCtlPWMClockSet(SYSCTL\_SYSDIV\_1);

    // Enable PWM0 peripheral and GPIO port B

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_PWM0);

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOB);

    // Configure pin B6 as PWM output

    GPIOPinConfigure(GPIO\_PB6\_M0PWM0);

    GPIOPinTypePWM(GPIO\_PORTB\_BASE, GPIO\_PIN\_6);

    // Configure PWM generator 0 in up-down count mode with no synchronization

    PWMGenConfigure(PWM0\_BASE, PWM\_GEN\_0, PWM\_GEN\_MODE\_UP\_DOWN | PWM\_GEN\_MODE\_NO\_SYNC);

    // Set the period of PWM generator 0 to 200000 cycles

    PWMGenPeriodSet(PWM0\_BASE, PWM\_GEN\_0, 200000);

    // Set the initial pulse width to 25% of the period

    PWMPulseWidthSet(PWM0\_BASE, PWM\_OUT\_0, PWMGenPeriodGet(PWM0\_BASE, PWM\_GEN\_0) / 4);

    // Enable PWM output for PWM0 output 0

    PWMOutputState(PWM0\_BASE, PWM\_OUT\_0\_BIT, true);

    // Enable PWM generator 0

    PWMGenEnable(PWM0\_BASE, PWM\_GEN\_0);

}

/\*\*

 \* @func    seat\_pwm\_init

 \* @brief   Initializes PWM for seat control

 \* @param   None

 \* @return  None

 \* @reference   TM4C123GH6PM examples

 \*/

void seat\_pwm\_init()

{

    // Set the PWM clock to run at the system clock divided by 1

    SysCtlPWMClockSet(SYSCTL\_SYSDIV\_1);

    // Enable PWM0 peripheral and GPIO port B

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_PWM0);

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOB);

    // Configure pin B7 as PWM output

    GPIOPinConfigure(GPIO\_PB7\_M0PWM1);

    GPIOPinTypePWM(GPIO\_PORTB\_BASE, GPIO\_PIN\_7);

    // Configure PWM generator 0 in up-down count mode with no synchronization

    PWMGenConfigure(PWM0\_BASE, PWM\_GEN\_0, PWM\_GEN\_MODE\_UP\_DOWN | PWM\_GEN\_MODE\_NO\_SYNC);

    // Set the period of PWM generator 0 to 200000 cycles

    PWMGenPeriodSet(PWM0\_BASE, PWM\_GEN\_0, 200000);

    // Enable PWM output for PWM0 output 1

    PWMOutputState(PWM0\_BASE, PWM\_OUT\_1\_BIT, true);

    // Enable PWM generator 0

    PWMGenEnable(PWM0\_BASE, PWM\_GEN\_0);

    // Enable GPIO port C and configure pins C6 and C7 as GPIO outputs

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOC);

    GPIOPinTypeGPIOOutput(GPIO\_PORTC\_BASE, GPIO\_PIN\_6);

    GPIOPinTypeGPIOOutput(GPIO\_PORTC\_BASE, GPIO\_PIN\_7);

    // Set pin C6 high and pin C7 low

    GPIOPinWrite(GPIO\_PORTC\_BASE, GPIO\_PIN\_6, GPIO\_PIN\_6);

    GPIOPinWrite(GPIO\_PORTC\_BASE, GPIO\_PIN\_7, 0);

}

/\*\*

 \* @func    servo\_init

 \* @brief   Initializes PWM for servo motor control

 \* @param   None

 \* @return  None

 \* @reference   https://github.com/smalik007/Servo-controlled-by-Tiva-C-Series-ARM-Cortex-M3-

 \*/

void servo\_init()

{

    // Set the PWM clock to the system clock divided by 8

    SysCtlPWMClockSet(SYSCTL\_PWMDIV\_8);

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_PWM1);

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOA);

    // Configure pin A7 as PWM output

    GPIOPinConfigure(GPIO\_PA7\_M1PWM3);

    GPIOPinTypePWM(GPIO\_PORTA\_BASE, GPIO\_PIN\_7);

    // Configure PWM generator 1 in down count mode with no synchronization

    PWMGenConfigure(PWM1\_BASE, PWM\_GEN\_1, PWM\_GEN\_MODE\_DOWN | PWM\_GEN\_MODE\_NO\_SYNC);

    // Set the period of PWM generator 1 to 40000 cycles

    PWMGenPeriodSet(PWM1\_BASE, PWM\_GEN\_1, 40000);

}

/\*\*

 \* @func    servo\_write

 \* @brief   Writes the desired angle to the servo motor

 \* @param   deg: Desired angle (0 to 180 degrees)

 \* @return  None

 \* @reference   https://github.com/smalik007/Servo-controlled-by-Tiva-C-Series-ARM-Cortex-M3-

 \*/

void servo\_write(float deg)

{

    // Calculate the duty cycle based on the desired angle

    float duty = ((deg / 90) + 0.4);

    float ticks = duty \* 2;

    float divf = (40 / ticks);

    int divfact = (int) divf;

    // Set the PWM pulse width based on the calculated divisor factor

    PWMPulseWidthSet(PWM1\_BASE, PWM\_OUT\_3, PWMGenPeriodGet(PWM1\_BASE, PWM\_GEN\_1) / divfact);

    PWMOutputState(PWM1\_BASE, PWM\_OUT\_3\_BIT, true);

    PWMGenEnable(PWM1\_BASE, PWM\_GEN\_1);

    // Delay for servo motor to reach the desired position

    SysCtlDelay((SysCtlClockGet() \* 0.3) / 3);

    // Disable PWM output after reaching the desired position

    PWMOutputState(PWM1\_BASE, PWM\_OUT\_3\_BIT, false);

    PWMGenDisable(PWM1\_BASE, PWM\_GEN\_1);

}

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file temperature\_sensor.h

 \* @brief Temperature sensor initialization and Access API's

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

#include <stdint.h>

#define TEMP\_OFFSET (5)

void tmp\_sensor\_init();

uint16\_t tmp\_readdata(void);

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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/\*\*

 \* @file temperature\_sensor.c

 \* @brief Temperature sensor initialization and Access API's

 \* @author Jithendra and Suhas

 \* @date 2024-4-29

 \*/

#define TARGET\_IS\_TM4C123\_RA1

#include "temperature\_sensor.h"

#include <stdbool.h>

#include <stdint.h>

#include "inc/hw\_memmap.h"

#include "inc/hw\_types.h"

#include "inc/hw\_ints.h"

#include "driverlib/gpio.h"

#include "driverlib/pin\_map.h"

#include "driverlib/rom.h"

#include "driverlib/sysctl.h"

#include "driverlib/ssi.h"

/\*\*

 \* @func    tmp\_sensor\_init

 \* @brief   Initializes the temperature sensor (TMP) via SPI (SSI0)

 \* @param   None

 \* @return  None

 \* @reference   TMP Sensor Datasheet, TM4C123GH6PM example

 \*/

void tmp\_sensor\_init()

{

    // Enable the SSI0 peripheral and GPIO port A

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_SSI0);

    SysCtlPeripheralEnable(SYSCTL\_PERIPH\_GPIOA);

    // Configure pins PA2, PA3, PA4, PA5 as SSI0 pins

    GPIOPinConfigure(GPIO\_PA2\_SSI0CLK);

    GPIOPinConfigure(GPIO\_PA3\_SSI0FSS);

    GPIOPinConfigure(GPIO\_PA4\_SSI0RX);

    GPIOPinConfigure(GPIO\_PA5\_SSI0TX);

    GPIOPinTypeSSI(GPIO\_PORTA\_BASE, GPIO\_PIN\_5 | GPIO\_PIN\_4 | GPIO\_PIN\_3 | GPIO\_PIN\_2);

    // Configure SSI0 to operate as a master, using Motorola SPI mode 0, with a clock speed of 1 MHz and 16-bit data frames

    SSIConfigSetExpClk(SSI0\_BASE, SysCtlClockGet(), SSI\_FRF\_MOTO\_MODE\_0, SSI\_MODE\_MASTER, 1000000, 16);

    // Enable the SSI0 module

    SSIEnable(SSI0\_BASE);

}

/\*\*

 \* @func    tmp\_readdata

 \* @brief   Reads temperature data from the TMP sensor

 \* @param   None

 \* @return  uint16\_t: Temperature data (in degrees Celsius)

 \* @reference   TMP Sensor Datasheet, TM4C123GH6PM example

 \*/

uint16\_t tmp\_readdata(void)

{

    uint32\_t ui32Data;

    uint16\_t tempData;

    // Wait until there is no data in the receive FIFO

    while (SSIDataGetNonBlocking(SSI0\_BASE, &ui32Data))

        ;

    // Send a dummy byte (0x00) to initiate the SPI transaction and receive data from the temperature sensor

    SSIDataPut(SSI0\_BASE, 0x00);

    SSIDataGet(SSI0\_BASE, &ui32Data);

    // Convert the received data to temperature using the sensor's data format

    tempData = (uint16\_t)(ui32Data >> 2) \* 0.25;

    // Return the temperature data

    return tempData;

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// Startup code for use with TI's Code Composer Studio.

//

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//

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// DAMAGES, FOR ANY REASON WHATSOEVER.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

#include <stdint.h>

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// Forward declaration of the default fault handlers.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void ResetISR(void);

static void NmiSR(void);

static void FaultISR(void);

static void IntDefaultHandler(void);

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// External declaration for the reset handler that is to be called when the

// processor is started

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

extern void \_c\_int00(void);

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// Linker variable that marks the top of the stack.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

extern uint32\_t \_\_STACK\_TOP;

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// External declarations for the interrupt handlers used by the application.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

extern void ButtonHandler(void);

extern void Timer0IntHandler(void);

extern void xPortPendSVHandler(void);

extern void vPortSVCHandler(void);

extern void xPortSysTickHandler(void);

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// The vector table.  Note that the proper constructs must be placed on this to

// ensure that it ends up at physical address 0x0000.0000 or at the start of

// the program if located at a start address other than 0.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

#pragma DATA\_SECTION(g\_pfnVectors, ".intvecs")

void (\* const g\_pfnVectors[])(void) =

{

    (void (\*)(void))((uint32\_t)&\_\_STACK\_TOP),

                                            // The initial stack pointer

    ResetISR,                               // The reset handler

    NmiSR,                                  // The NMI handler

    FaultISR,                               // The hard fault handler

    IntDefaultHandler,                      // The MPU fault handler

    IntDefaultHandler,                      // The bus fault handler

    IntDefaultHandler,                      // The usage fault handler

    0,                                      // Reserved

    0,                                      // Reserved

    0,                                      // Reserved

    0,                                      // Reserved

    vPortSVCHandler,                      // SVCall handler

    IntDefaultHandler,                      // Debug monitor handler

    0,                                      // Reserved

    xPortPendSVHandler,                      // The PendSV handler

    xPortSysTickHandler,                      // The SysTick handler

    IntDefaultHandler,                      // GPIO Port A

    IntDefaultHandler,                      // GPIO Port B

    IntDefaultHandler,                      // GPIO Port C

    IntDefaultHandler,                      // GPIO Port D

    IntDefaultHandler,                      // GPIO Port E

    IntDefaultHandler,                      // UART0 Rx and Tx

    IntDefaultHandler,                      // UART1 Rx and Tx

    IntDefaultHandler,                      // SSI0 Rx and Tx

    IntDefaultHandler,                      // I2C0 Master and Slave

    IntDefaultHandler,                      // PWM Fault

    IntDefaultHandler,                      // PWM Generator 0

    IntDefaultHandler,                      // PWM Generator 1

    IntDefaultHandler,                      // PWM Generator 2

    IntDefaultHandler,                      // Quadrature Encoder 0

    IntDefaultHandler,                      // ADC Sequence 0

    IntDefaultHandler,                      // ADC Sequence 1

    IntDefaultHandler,                      // ADC Sequence 2

    IntDefaultHandler,                      // ADC Sequence 3

    IntDefaultHandler,                      // Watchdog timer

    Timer0IntHandler,                      // Timer 0 subtimer A

    IntDefaultHandler,                      // Timer 0 subtimer B

    IntDefaultHandler,                      // Timer 1 subtimer A

    IntDefaultHandler,                      // Timer 1 subtimer B

    IntDefaultHandler,                      // Timer 2 subtimer A

    IntDefaultHandler,                      // Timer 2 subtimer B

    IntDefaultHandler,                      // Analog Comparator 0

    IntDefaultHandler,                      // Analog Comparator 1

    IntDefaultHandler,                      // Analog Comparator 2

    IntDefaultHandler,                      // System Control (PLL, OSC, BO)

    IntDefaultHandler,                      // FLASH Control

    ButtonHandler,                      // GPIO Port F

    IntDefaultHandler,                      // GPIO Port G

    IntDefaultHandler,                      // GPIO Port H

    IntDefaultHandler,                      // UART2 Rx and Tx

    IntDefaultHandler,                      // SSI1 Rx and Tx

    IntDefaultHandler,                      // Timer 3 subtimer A

    IntDefaultHandler,                      // Timer 3 subtimer B

    IntDefaultHandler,                      // I2C1 Master and Slave

    IntDefaultHandler,                      // Quadrature Encoder 1

    IntDefaultHandler,                      // CAN0

    IntDefaultHandler,                      // CAN1

    0,                                      // Reserved

    0,                                      // Reserved

    IntDefaultHandler,                      // Hibernate

    IntDefaultHandler,                      // USB0

    IntDefaultHandler,                      // PWM Generator 3

    IntDefaultHandler,                      // uDMA Software Transfer

    IntDefaultHandler,                      // uDMA Error

    IntDefaultHandler,                      // ADC1 Sequence 0

    IntDefaultHandler,                      // ADC1 Sequence 1

    IntDefaultHandler,                      // ADC1 Sequence 2

    IntDefaultHandler,                      // ADC1 Sequence 3

    0,                                      // Reserved

    0,                                      // Reserved

    IntDefaultHandler,                      // GPIO Port J

    IntDefaultHandler,                      // GPIO Port K

    IntDefaultHandler,                      // GPIO Port L

    IntDefaultHandler,                      // SSI2 Rx and Tx

    IntDefaultHandler,                      // SSI3 Rx and Tx

    IntDefaultHandler,                      // UART3 Rx and Tx

    IntDefaultHandler,                      // UART4 Rx and Tx

    IntDefaultHandler,                      // UART5 Rx and Tx

    IntDefaultHandler,                      // UART6 Rx and Tx

    IntDefaultHandler,                      // UART7 Rx and Tx

    0,                                      // Reserved

    0,                                      // Reserved

    0,                                      // Reserved

    0,                                      // Reserved

    IntDefaultHandler,                      // I2C2 Master and Slave

    IntDefaultHandler,                      // I2C3 Master and Slave

    IntDefaultHandler,                      // Timer 4 subtimer A

    IntDefaultHandler,                      // Timer 4 subtimer B

    0,                                      // Reserved

    0,                                      // Reserved

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    0,                                      // Reserved

    IntDefaultHandler,                      // Timer 5 subtimer A

    IntDefaultHandler,                      // Timer 5 subtimer B

    IntDefaultHandler,                      // Wide Timer 0 subtimer A

    IntDefaultHandler,                      // Wide Timer 0 subtimer B

    IntDefaultHandler,                      // Wide Timer 1 subtimer A

    IntDefaultHandler,                      // Wide Timer 1 subtimer B

    IntDefaultHandler,                      // Wide Timer 2 subtimer A

    IntDefaultHandler,                      // Wide Timer 2 subtimer B

    IntDefaultHandler,                      // Wide Timer 3 subtimer A

    IntDefaultHandler,                      // Wide Timer 3 subtimer B

    IntDefaultHandler,                      // Wide Timer 4 subtimer A

    IntDefaultHandler,                      // Wide Timer 4 subtimer B

    IntDefaultHandler,                      // Wide Timer 5 subtimer A

    IntDefaultHandler,                      // Wide Timer 5 subtimer B

    IntDefaultHandler,                      // FPU

    0,                                      // Reserved

    0,                                      // Reserved

    IntDefaultHandler,                      // I2C4 Master and Slave

    IntDefaultHandler,                      // I2C5 Master and Slave

    IntDefaultHandler,                      // GPIO Port M

    IntDefaultHandler,                      // GPIO Port N

    IntDefaultHandler,                      // Quadrature Encoder 2

    0,                                      // Reserved

    0,                                      // Reserved

    IntDefaultHandler,                      // GPIO Port P (Summary or P0)

    IntDefaultHandler,                      // GPIO Port P1

    IntDefaultHandler,                      // GPIO Port P2

    IntDefaultHandler,                      // GPIO Port P3

    IntDefaultHandler,                      // GPIO Port P4

    IntDefaultHandler,                      // GPIO Port P5

    IntDefaultHandler,                      // GPIO Port P6

    IntDefaultHandler,                      // GPIO Port P7

    IntDefaultHandler,                      // GPIO Port Q (Summary or Q0)

    IntDefaultHandler,                      // GPIO Port Q1

    IntDefaultHandler,                      // GPIO Port Q2

    IntDefaultHandler,                      // GPIO Port Q3

    IntDefaultHandler,                      // GPIO Port Q4

    IntDefaultHandler,                      // GPIO Port Q5

    IntDefaultHandler,                      // GPIO Port Q6

    IntDefaultHandler,                      // GPIO Port Q7

    IntDefaultHandler,                      // GPIO Port R

    IntDefaultHandler,                      // GPIO Port S

    IntDefaultHandler,                      // PWM 1 Generator 0

    IntDefaultHandler,                      // PWM 1 Generator 1

    IntDefaultHandler,                      // PWM 1 Generator 2

    IntDefaultHandler,                      // PWM 1 Generator 3

    IntDefaultHandler                       // PWM 1 Fault

};

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// This is the code that gets called when the processor first starts execution

// following a reset event.  Only the absolutely necessary set is performed,

// after which the application supplied entry() routine is called.  Any fancy

// actions (such as making decisions based on the reset cause register, and

// resetting the bits in that register) are left solely in the hands of the

// application.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void

ResetISR(void)

{

    //

    // Jump to the CCS C initialization routine.  This will enable the

    // floating-point unit as well, so that does not need to be done here.

    //

    \_\_asm("    .global \_c\_int00\n"

          "    b.w     \_c\_int00");

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// This is the code that gets called when the processor receives a NMI.  This

// simply enters an infinite loop, preserving the system state for examination

// by a debugger.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

static void

NmiSR(void)

{

    //

    // Enter an infinite loop.

    //

    while(1)

    {

    }

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// This is the code that gets called when the processor receives a fault

// interrupt.  This simply enters an infinite loop, preserving the system state

// for examination by a debugger.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

static void

FaultISR(void)

{

    //

    // Enter an infinite loop.

    //

    while(1)

    {

    }

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

//

// This is the code that gets called when the processor receives an unexpected

// interrupt.  This simply enters an infinite loop, preserving the system state

// for examination by a debugger.

//

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

static void

IntDefaultHandler(void)

{

    //

    // Go into an infinite loop.

    //

    while(1)

    {

    }

}