A PROJECT ON

AutoSense CAN : Adaptive Automotive System

SUBMITTED IN

PARTIAL FULFILLMENT OF THE REQUIREMENT

FOR THE COURSE OF DIPLOMA IN EMBEDDED SYSTEMS AND DESIGN FROM CDAC

SUNBEAM INSTITUTE OF INFORMATION TECHNOLOGY

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PG-DESD

1. Introduction

1.1 Project Overview

The AutoSense CAN Adaptive Automotive System is an advanced automotive project designed to improve vehicle safety, efficiency, and performance by integrating a network of smart sensors. This system automates crucial vehicle functions such as headlight brightness adjustment, obstacle detection near doors, and monitoring of high voltage and current drawn by DC motors. The data collected by these sensors is analyzed in real-time to provide continuous system improvements.

1.2 Objectives

- **Headlight Control:** Automate the adjustment of headlight brightness according to real-time road lighting conditions.
- **Obstacle Detection:** Ensure safe passenger egress by detecting obstacles near vehicle doors using PIR sensors.
- **Electrical Monitoring:** Continuously monitor voltage and current levels in the vehicle's DC motors to prevent malfunctions.
- **Data Analytics:** Store and analyze sensor data in real-time for system optimization and predictive maintenance.

1.3 Motivation

With the growing complexity of automotive systems, there is a need for intelligent systems that can adapt to changing driving conditions while enhancing vehicle safety. The AutoSense CAN Adaptive Automotive System meets this need by employing advanced sensor technology and real-time data analytics to deliver a safer and more efficient driving experience.

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2. System Design and Components

2.1 Overview of the System Architecture

The system architecture is based on the Controller Area Network (CAN) protocol, which enables communication between the various sensors and the central processing unit (CPU). The architecture is designed for real-time operation, where sensor data is continuously monitored and processed to make immediate adjustments to vehicle systems.

2.2 Hardware Components and Their Functions

2.2.1 LDR Sensors (Light Dependent Resistors)

- **Functionality in the Project:**
  - LDR sensors are used to measure the ambient light levels around the vehicle. These sensors provide input to the CPU, which then adjusts the brightness of the vehicle's headlights. The goal is to optimize visibility while driving, ensuring that the headlights are neither too dim in low-light conditions nor too bright in well-lit areas.
- **Working Principle:**
  - LDRs change their resistance based on the amount of light falling on them. In low light, the resistance increases, signaling the CPU to increase the headlight brightness. In bright conditions, the resistance decreases, prompting the system to reduce headlight intensity.
- **Specifications:**
  - **Resistance Range:** 10KΩ to 1MΩ (depending on light intensity)
  - **Operating Voltage:** 3.3V to 5V
- **Placement:** Installed near the headlights to accurately detect the surrounding light conditions.

2.2.2 PIR Sensors (Passive Infrared Sensors)

- **Functionality in the Project:**
  - PIR sensors detect the presence of obstacles near the vehicle's doors. These sensors help prevent doors from opening if an obstacle is detected, ensuring passenger safety during entry and exit.

- **Working Principle:**
    - PIR sensors detect infrared radiation emitted by objects. When an object enters the sensor's detection range, it triggers a signal to the CPU, which can then prevent the door from unlocking or opening.
- **Specifications:**
    - **Detection Range:** 5 to 10 meters
    - **Operating Voltage:** 3.3V to 5V
- **Placement:** Positioned around the door frames to monitor the area where passengers enter and exit the vehicle.

2.2.3 High Voltage/Current Sensors

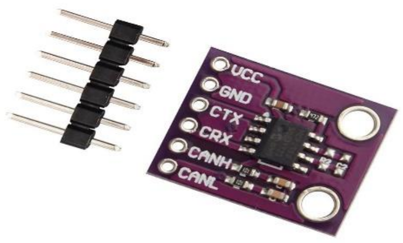
- **Functionality in the Project:**
    - These sensors monitor the voltage and current levels of the vehicle's DC motors. By keeping track of the electrical parameters, the system ensures that the motors operate within safe limits, preventing potential electrical faults that could lead to system failures.
- **Working Principle:**
    - The sensors measure the voltage across the motor terminals and the current flowing through the motor. If either the voltage or current exceeds predefined thresholds, the system can take corrective action, such as reducing the load or alerting the driver.
- **Specifications:**
    - **Voltage Range:** 0 to 50V
    - **Current Range:** 0 to 30A
    - **Accuracy:** ±1%
- **Placement:** Integrated into the vehicle's electrical system, typically close to the DC motors.

2.2.4 Central Processing Unit (CPU)

- **Functionality in the Project:**
    - The CPU acts as the brain of the system, processing the data received from all sensors. It runs algorithms to determine the appropriate responses, such as adjusting headlight brightness, blocking door access, or managing motor performance. The CPU also communicates with the CAN bus to ensure all components are synchronized.
- **Working Principle:**

    - The CPU receives digital signals from the sensors, processes this information in real-time, and sends control commands back to the vehicle systems. It also logs data for later analysis.
- **Specifications:**
    - **Microcontroller:** ARM Cortex-M4 or equivalent
    - **Clock Speed:** 80 MHz
    - **Memory:** 256KB Flash, 64KB RAM
- **Placement:** Installed in the vehicle's central control unit, interfacing with all connected sensors and the CAN network.

2.2.5 CAN Transceiver



- **Functionality in the Project:**
    - The CAN transceiver facilitates communication between the CPU and the sensors by converting the sensor data into CAN protocol messages. This ensures reliable and efficient data exchange across the vehicle's network.
- **Working Principle:**
    - The transceiver converts the electrical signals from the CPU into CAN messages and vice versa, allowing for seamless communication across the vehicle's network.
- **Specifications:**
    - **Operating Voltage:** 3.3V to 5V
    - **Data Rate:** Up to 1 Mbps
- **Placement:** Integrated with the CPU and connected to the CAN bus.

2.2.6 Power Supply Unit

- **Functionality in the Project:**
    - The power supply unit provides the necessary regulated power to all components, ensuring stable and reliable operation of the sensors, CPU, and CAN transceiver.
- **Working Principle:**
    - The power supply unit converts the vehicle's 12V battery power to the required 3.3V and 5V levels needed by the sensors and CPU.
- **Specifications:**
    - **Input Voltage:** 12V (vehicle battery)
    - **Output Voltage:** 3.3V and 5V (regulated)
- **Placement:** Connected to the vehicle's electrical system, distributing power to all connected components.

2.3 Data Collection and Storage

The system continuously collects data from the LDR, PIR, and high voltage/current sensors. This data is transmitted to a central server where it is stored for real-time analysis. The data logging is crucial for identifying patterns, diagnosing potential issues, and implementing system improvements over time.

Relay

The motor protection relay is an electrical device used to protect the motor. It can monitor and control the motor to avoid failure or damage to the motor during operation. Motor protection relays are an integral part of modern power systems.

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3. Implementation

3.1 System Integration

Integrating the hardware components into the CAN network is a critical aspect of the system. Each sensor is connected to the CAN bus through the CAN transceiver, which allows for smooth communication with the CPU. The CPU processes the sensor data and sends appropriate commands to adjust vehicle functions.

3.2 Software Development

Custom software was developed to manage data acquisition, processing, and control tasks. The software features include:

- **Sensor Data Processing:** Algorithms that interpret data from LDR, PIR, and voltage/current sensors to trigger appropriate actions, such as adjusting headlights or blocking door access.

- **CAN Communication Protocol:** Software that ensures efficient data transmission and reception within the CAN network.
- **Data Logging and Analytics:** Software modules that log sensor data to the central server and analyze it for system optimization and predictive maintenance.

3.3 Real-Time Data Processing

The system's real-time processing capabilities are essential for immediate response to sensor inputs. For instance, when the PIR sensor detects an obstacle, the system instantly prevents the door from opening. Similarly, the headlight brightness is adjusted in real-time based on the data from the LDR sensors.

CODE

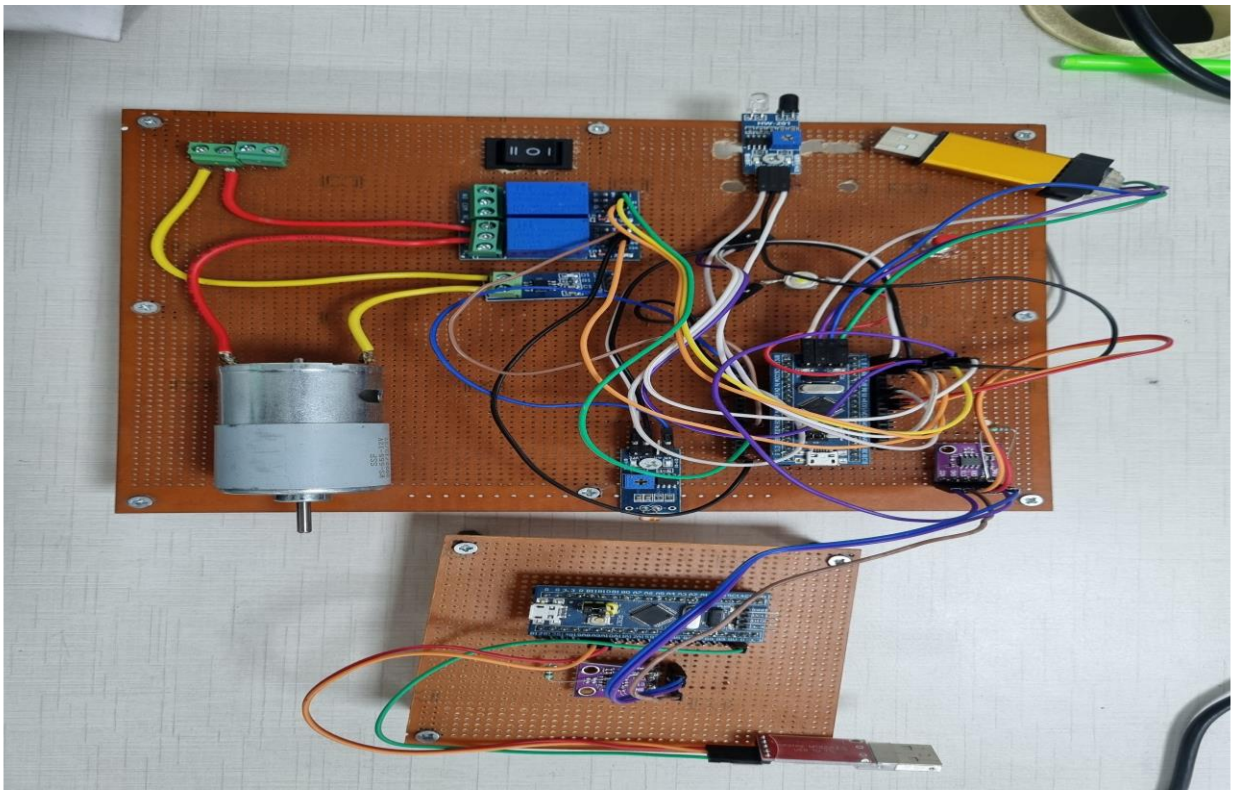
```
/* USER CODE BEGIN Header */

/**

  ******************************************************************************

  * @file           : main.c

  * @brief          : Main program body

  ******************************************************************************

  * @attention

  * Copyright (c) 2024 STMicroelectronics.

  * All rights reserved.

  *

  * This software is licensed under terms that can be found in the LICENSE file

  * in the root directory of this software component.

  * If no LICENSE file comes with this software, it is provided AS-IS.

  *

  ******************************************************************************

  */

/* USER CODE END Header */

/* Includes ------------------------------------------------------------------*/

#include "main.h"
```

```
/* Private includes ----------------------------------------------------------*/

/* USER CODE BEGIN Includes */

/* USER CODE END Includes */

/* Private typedef -----------------------------------------------------------*/

/* USER CODE BEGIN PTD */

/* USER CODE END PTD */

/* Private define ------------------------------------------------------------*/

/* USER CODE BEGIN PD */

/* USER CODE END PD */

/* Private macro -------------------------------------------------------------*/

/* USER CODE BEGIN PM */

/* USER CODE END PM */

/* Private variables ---------------------------------------------------------*/

ADC_HandleTypeDef hadc1;

DMA_HandleTypeDef hdma_adc1;

TIM_HandleTypeDef htim2;

UART_HandleTypeDef huart1;

/* USER CODE BEGIN PV */

uint16_t ldr;

uint16_t motor;

uint16_t motion;

uint8_t ldr_flag;

uint8_t motion_flag;

uint8_t motor_flag;

uint16_t door_sw;

uint16_t ir_state;

uint16_t data[8];

uint8_t send[3];

uint8_t text1 [] = "LDR:";
```

```
uint8_t text3 [] = "Motor:";

uint8_t text2 [] = "Motion:";

uint16_t raw_values[2];

/* USER CODE END PV */

/* Private function prototypes -----------------------------------------------*/

void SystemClock_Config(void);

static void MX_GPIO_Init(void);

static void MX_DMA_Init(void);

static void MX_ADC1_Init(void);

static void MX_TIM2_Init(void);

static void MX_USART1_UART_Init(void);

/* USER CODE BEGIN PFP */

uint8_t conversion_complete = 0;

void HAL_ADC_ConvCpltCallback(ADC_HandleTypeDef* hadc)

{

	conversion_complete = 1;

}

/* USER CODE END PFP */

/* Private user code ---------------------------------------------------------*/

/* USER CODE BEGIN 0 */

/* USER CODE END 0 */

/**

  * @brief  The application entry point.

  * @retval int

  */

int main(void)

{

  /* USER CODE BEGIN 1 */
  /* USER CODE END 1 */

  /* MCU Configuration--------------------------------------------------------*/

  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */

  HAL_Init();

  /* USER CODE BEGIN Init */

  /* USER CODE END Init */

  /* Configure the system clock */

  SystemClock_Config();

  /* USER CODE BEGIN SysInit */

  /* USER CODE END SysInit */

  /* Initialize all configured peripherals */

  MX_GPIO_Init();

  MX_DMA_Init();

  MX_ADC1_Init();

  HAL_GPIO_WritePin(relay_sw_GPIO_Port, relay_sw_Pin, 1);

  MX_TIM2_Init();

  MX_USART1_UART_Init();

  /* USER CODE BEGIN 2 */

  HAL_TIM_PWM_Start(&htim2, TIM_CHANNEL_2);

/* USER CODE BEGIN 2 */

  HAL_ADC_Start_DMA(&hadc1, (uint32_t *)raw_values, 2);

  /* USER CODE END 2 */

  /* Infinite loop */

  /* USER CODE BEGIN WHILE */

  while (1)

   {

    /* USER CODE END WHILE */

            while (!conversion_complete);

            for (uint8_t i=0; i<hadc1.Init.NbrOfConversion;i++){
                ldr = (uint16_t) raw_values[0];

                motor = (uint16_t) raw_values[1];

    }

    if (HAL_GPIO_ReadPin(Door_sw_GPIO_Port, Door_sw_Pin) == GPIO_PIN_RESET){

                door_sw = 1;

                if (HAL_GPIO_ReadPin(IR_GPIO_Port, IR_Pin) == GPIO_PIN_RESET){

                        HAL_GPIO_WritePin(second_relay_GPIO_Port, second_relay_Pin, 1);

                        motion_flag =1;

                        HAL_UART_Transmit(&huart1, text2, 7, 1000);

                        HAL_Delay(200);

                        sprintf(data, "%d\n", motion_flag);

                        HAL_UART_Transmit(&huart1, data, 3, 1000);

                        HAL_Delay(5000);

               }

                else{

                        HAL_GPIO_WritePin(second_relay_GPIO_Port, second_relay_Pin, 0);

                        motion_flag =0;

                }

    }

    else {

                door_sw = 0;

                HAL_GPIO_WritePin(second_relay_GPIO_Port, second_relay_Pin, 1);

    }

   motion_flag = 0;

    if (HAL_GPIO_ReadPin(IR_GPIO_Port, IR_Pin) == GPIO_PIN_RESET){

                motion_flag = 1;

    }

    else {

                motion_flag = 0;
```

```
}
        if (HAL_GPIO_ReadPin(Relay_Switch_GPIO_Port, Relay_Switch_Pin) == GPIO_PIN_RESET){
                HAL_GPIO_WritePin(relay_sw_GPIO_Port, relay_sw_Pin, 0);
                motor_flag = 1;
        }
        else{
                HAL_GPIO_WritePin(relay_sw_GPIO_Port, relay_sw_Pin, 1);
                motor_flag =0;
        }
        if(ldr >3000){
                __HAL_TIM_SET_COMPARE(&htim2,TIM_CHANNEL_2, 4096);
                ldr_flag = 1;
                HAL_Delay(30);
        }
        else{
                __HAL_TIM_SET_COMPARE(&htim2,TIM_CHANNEL_2, 0);
                ldr_flag = 0;
        }
        HAL_UART_Transmit(&huart1, text1, 4, 1000);
        HAL_Delay(200);
        sprintf(data, "%d\n", ldr_flag);
        HAL_UART_Transmit(&huart1, data, 3, 1000);
        HAL_Delay(200);
        HAL_UART_Transmit(&huart1, text2, 7, 1000);
        HAL_Delay(200);
        sprintf(data, "%d\n", motion_flag);
        HAL_UART_Transmit(&huart1, data, 3, 1000);
        HAL_Delay(200);
        HAL_UART_Transmit(&huart1, text3, 6, 1000);
        HAL_Delay(200);

        sprintf(data, "%d\n", motor_flag);

        HAL_UART_Transmit(&huart1, data, 3, 1000);

        HAL_Delay(200);

    }

  /* USER CODE END 3 */

}

/**

  * @brief System Clock Configuration

  * @retval None

  */

void SystemClock_Config(void)

{

  RCC_OscInitTypeDef RCC_OscInitStruct = {0};

  RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};

  RCC_PeriphCLKInitTypeDef PeriphClkInit = {0};

  /** Initializes the RCC Oscillators according to the specified parameters

  * in the RCC_OscInitTypeDef structure.

  */

  RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSE;

  RCC_OscInitStruct.HSEState = RCC_HSE_ON;

  RCC_OscInitStruct.PLL.PLLState = RCC_PLL_NONE;

  if (HAL_RCC_OscConfig(&RCC_OscInitStruct) != HAL_OK)

  {

    Error_Handler();

  }

  /** Initializes the CPU, AHB and APB buses clocks

  */

  RCC_ClkInitStruct.ClockType = RCC_CLOCKTYPE_HCLK|RCC_CLOCKTYPE_SYSCLK
```

```
                              |RCC_CLOCKTYPE_PCLK1|RCC_CLOCKTYPE_PCLK2;
  RCC_ClkInitStruct.SYSCLKSource = RCC_SYSCLKSOURCE_HSE;
  RCC_ClkInitStruct.AHBCLKDivider = RCC_SYSCLK_DIV1;
  RCC_ClkInitStruct.APB1CLKDivider = RCC_HCLK_DIV1;
  RCC_ClkInitStruct.APB2CLKDivider = RCC_HCLK_DIV1;
  if (HAL_RCC_ClockConfig(&RCC_ClkInitStruct, FLASH_LATENCY_0) != HAL_OK)
  {
    Error_Handler();
  }
  PeriphClkInit.PeriphClockSelection = RCC_PERIPHCLK_ADC;
  PeriphClkInit.AdcClockSelection = RCC_ADCPCLK2_DIV2;
  if (HAL_RCCEx_PeriphCLKConfig(&PeriphClkInit) != HAL_OK)
  {
    Error_Handler();
  }
}
/**
  * @brief ADC1 Initialization Function
  * @param None
  * @retval None
  */
static void MX_ADC1_Init(void)
{
  /* USER CODE BEGIN ADC1_Init 0 */
  /* USER CODE END ADC1_Init 0 */
  ADC_ChannelConfTypeDef sConfig = {0};
  /* USER CODE BEGIN ADC1_Init 1 */
  /* USER CODE END ADC1_Init 1 */
  /** Common config
  */
  hadc1.Instance = ADC1;
  hadc1.Init.ScanConvMode = ADC_SCAN_ENABLE;
  hadc1.Init.ContinuousConvMode = ENABLE;
  hadc1.Init.DiscontinuousConvMode = DISABLE;
  hadc1.Init.ExternalTrigConv = ADC_SOFTWARE_START;
  hadc1.Init.DataAlign = ADC_DATAALIGN_RIGHT;
  hadc1.Init.NbrOfConversion = 2;
  if (HAL_ADC_Init(&hadc1) != HAL_OK)
  {
    Error_Handler();
  }
  /** Configure Regular Channel
  */
  sConfig.Channel = ADC_CHANNEL_0;
  sConfig.Rank = ADC_REGULAR_RANK_1;
  sConfig.SamplingTime = ADC_SAMPLETIME_239CYCLES_5;
  if (HAL_ADC_ConfigChannel(&hadc1, &sConfig) != HAL_OK)
  {
    Error_Handler();
  }
/** Configure Regular Channel
  */
  sConfig.Channel = ADC_CHANNEL_2;
  sConfig.Rank = ADC_REGULAR_RANK_2;
  if (HAL_ADC_ConfigChannel(&hadc1, &sConfig) != HAL_OK)
  {
    Error_Handler();
  }
  /* USER CODE BEGIN ADC1_Init 2 */

  /* USER CODE END ADC1_Init 2 */

}

/**

  * @brief TIM2 Initialization Function

  * @param None

  * @retval None

  */

static void MX_TIM2_Init(void)

{

/* USER CODE BEGIN TIM2_Init 0 */

  /* USER CODE END TIM2_Init 0 */

  TIM_ClockConfigTypeDef sClockSourceConfig = {0};

  TIM_MasterConfigTypeDef sMasterConfig = {0};

  TIM_OC_InitTypeDef sConfigOC = {0};

  /* USER CODE BEGIN TIM2_Init 1 */

  /* USER CODE END TIM2_Init 1 */

  htim2.Instance = TIM2;

  htim2.Init.Prescaler = 127;

  htim2.Init.CounterMode = TIM_COUNTERMODE_UP;

  htim2.Init.Period = 4096;

  htim2.Init.ClockDivision = TIM_CLOCKDIVISION_DIV1;

  htim2.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;

  if (HAL_TIM_Base_Init(&htim2) != HAL_OK)

  {

    Error_Handler();

  }

  sClockSourceConfig.ClockSource = TIM_CLOCKSOURCE_INTERNAL;

  if (HAL_TIM_ConfigClockSource(&htim2, &sClockSourceConfig) != HAL_OK)
  {
    Error_Handler();
  }
  if (HAL_TIM_PWM_Init(&htim2) != HAL_OK)
  {
    Error_Handler();
  }
  sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
  sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
  if (HAL_TIMEx_MasterConfigSynchronization(&htim2, &sMasterConfig) != HAL_OK)
  {
    Error_Handler();
  }
  sConfigOC.OCMode = TIM_OCMODE_PWM1;
  sConfigOC.Pulse = 0;
  sConfigOC.OCPolarity = TIM_OCPOLARITY_HIGH;
  sConfigOC.OCFastMode = TIM_OCFAST_DISABLE;
  if (HAL_TIM_PWM_ConfigChannel(&htim2, &sConfigOC, TIM_CHANNEL_2) != HAL_OK)
  {
    Error_Handler();
  }
  /* USER CODE BEGIN TIM2_Init 2 */
  /* USER CODE END TIM2_Init 2 */
  HAL_TIM_MspPostInit(&htim2);
}
/**
  * @brief USART1 Initialization Function
  * @param None
  * @retval None
  */
static void MX_USART1_UART_Init(void)
{
/* USER CODE BEGIN USART1_Init 0 */
  /* USER CODE END USART1_Init 0 */
  /* USER CODE BEGIN USART1_Init 1 */
  /* USER CODE END USART1_Init 1 */
  huart1.Instance = USART1;
  huart1.Init.BaudRate = 115200;
  huart1.Init.WordLength = UART_WORDLENGTH_8B;
  huart1.Init.StopBits = UART_STOPBITS_1;
  huart1.Init.Parity = UART_PARITY_NONE;
  huart1.Init.Mode = UART_MODE_TX_RX;
  huart1.Init.HwFlowCtl = UART_HWCONTROL_NONE;
  huart1.Init.OverSampling = UART_OVERSAMPLING_16;
  if (HAL_UART_Init(&huart1) != HAL_OK)
  {
    Error_Handler();
  }
  /* USER CODE BEGIN USART1_Init 2 */
  /* USER CODE END USART1_Init 2 */
}
/**
  * Enable DMA controller clock
  */
static void MX_DMA_Init(void)
{
  /* DMA controller clock enable */
  __HAL_RCC_DMA1_CLK_ENABLE();
  /* DMA interrupt init */
  /* DMA1_Channel1_IRQn interrupt configuration */
  HAL_NVIC_SetPriority(DMA1_Channel1_IRQn, 0, 0);
  HAL_NVIC_EnableIRQ(DMA1_Channel1_IRQn);
}
/**
  * @brief GPIO Initialization Function
  * @param None
  * @retval None
  */
static void MX_GPIO_Init(void)
{
  GPIO_InitTypeDef GPIO_InitStruct = {0};
/* USER CODE BEGIN MX_GPIO_Init_1 */
/* USER CODE END MX_GPIO_Init_1 */
/* GPIO Ports Clock Enable */
  __HAL_RCC_GPIOD_CLK_ENABLE();
  __HAL_RCC_GPIOA_CLK_ENABLE();
  __HAL_RCC_GPIOB_CLK_ENABLE();

  /*Configure GPIO pin Output Level */
  HAL_GPIO_WritePin(GPIOB, relay_sw_Pin|second_relay_Pin, GPIO_PIN_RESET);

  /*Configure GPIO pins : relay_sw_Pin second_relay_Pin */
  GPIO_InitStruct.Pin = relay_sw_Pin|second_relay_Pin;
  GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
  GPIO_InitStruct.Pull = GPIO_NOPULL;
  GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
  HAL_GPIO_Init(GPIOB, &GPIO_InitStruct);


  /*Configure GPIO pins : Relay_Switch_Pin Door_sw_Pin */
  GPIO_InitStruct.Pin = Relay_Switch_Pin|Door_sw_Pin;
  GPIO_InitStruct.Mode = GPIO_MODE_INPUT;
  GPIO_InitStruct.Pull = GPIO_PULLUP;
  HAL_GPIO_Init(GPIOB, &GPIO_InitStruct);


  /*Configure GPIO pins : pir_Pin IR_Pin */
  GPIO_InitStruct.Pin = pir_Pin|IR_Pin;
  GPIO_InitStruct.Mode = GPIO_MODE_INPUT;
  GPIO_InitStruct.Pull = GPIO_NOPULL;
  HAL_GPIO_Init(GPIOB, &GPIO_InitStruct);


/* USER CODE BEGIN MX_GPIO_Init_2 */
/* USER CODE END MX_GPIO_Init_2 */
}


/* USER CODE BEGIN 4 */


/* USER CODE END 4 */


/**
  * @brief  This function is executed in case of error occurrence.
  * @retval None
  */
void Error_Handler(void)
{
  /* USER CODE BEGIN Error_Handler_Debug */
  /* User can add his own implementation to report the HAL error return state */
  __disable_irq();
  while (1)
  {
  }
  /* USER CODE END Error_Handler_Debug */
}

#ifdef  USE_FULL_ASSERT
/**
  * @brief  Reports the name of the source file and the source line number
  *         where the assert_param error has occurred.
  * @param  file: pointer to the source file name
  * @param  line: assert_param error line source number
  * @retval None
  */
void assert_failed(uint8_t *file, uint32_t line)
{
  /* USER CODE BEGIN 6 */
  /* User can add his own implementation to report the file name and line number,
     ex: printf("Wrong parameters value: file %s on line %d\r\n", file, line) */
  /* USER CODE END 6 */
}
#endif /* USE_FULL_ASSERT */
```



4. Testing and Results

4.1 Testing Procedures

The system was tested under various scenarios to ensure its reliability and effectiveness:

- **Headlight Brightness Control:** Tested across different lighting conditions, from daylight to nighttime, to validate the system's ability to adjust headlight brightness accurately.
- **Obstacle Detection:** Simulated various obstacles to ensure the PIR sensors reliably detect objects near the doors and prevent them from opening.
- **Voltage/Current Monitoring:** Tested the system under varying motor loads to ensure accurate monitoring of voltage and current, and the system's ability to respond to electrical anomalies.

4.2 Results

The tests confirmed that the AutoSense CAN Adaptive Automotive System performs effectively in real-world conditions:

- The LDR sensors successfully adjusted headlight brightness based on ambient light conditions.
- The PIR sensors reliably detected obstacles, ensuring passenger safety during door operation.
- The voltage/current sensors accurately monitored the electrical parameters of the DC motors, and the system responded appropriately to any anomalies.

The data collected during testing was logged on the central server and provided valuable insights for further refinement of the system.

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5. Conclusion and Future Work

5.1 Conclusion

The AutoSense CAN Adaptive Automotive System demonstrates the potential of integrating advanced sensor technologies into automotive systems to enhance safety and performance. By automating key functions and providing real-time data analysis, the system offers a significant improvement in vehicle operation and passenger safety