

HOME APPLICATION CONTROL

Introduction to embedded systems project



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Team members

# **Project Overview**

The Home Appliances Control System is a comprehensive solution that enables users to monitor and control various home appliances through a mobile application. The system implements a layered architecture approach, consisting of three main layers:

## 1. Application Layer

- Android mobile application providing user interface for control and monitoring

- Handles user interactions and displays system status

- Implements temperature alarm logic and door status logging

- Manages Bluetooth communication with the microcontroller

## 2. Hardware Abstraction Layer (HAL)

(magnetic\_switch.c/h, temp.c/h, lamp\_plug.c/h, bluetooth\_module.c/h)

- Provides abstract interface between hardware and middleware

- Implements device drivers for:

- Temperature sensor

- Relay modules

- Magnetic door switch

- Bluetooth module

- Physical alarm

- Handles hardware initialization and configuration

## 3. Middleware/Mechanical Layer

( tm4c123gh6pm.h, DIO.c/h, adc.c/h, adc.c/h, uart.c/h , Systick.c/h, utils.h ,startup\_ewarm.c)

-Manages communication protocols between application and hardware

- Implements control logic for appliance switching

- Handles sensor data processing and formatting

- Manages state transitions and system timing

- Provides error handling and system stability

# **System Architecture Overview**

The system utilizes a TM4C123GH6PM microcontroller as its core processing unit, interfacing with various peripheral devices and sensors.

# **Hardware Implementation**

## Core Components:

### 1. Processing Unit

- TM4C123GH6PM microcontroller

- Operating at 16MHz

- Utilizing GPIO, ADC, and UART peripherals

### 2. Power Management

- 5V DC power supply for microcontroller and sensors

- 220V AC handling through isolated relay modules

- Voltage regulation and protection circuits

### 3. Sensing Elements

- Temperature sensor for room monitoring

- Magnetic reed switch for door status detection

- Status LEDs for visual feedback

### 4. Control Elements

- Relay modules for lamp and plug control

- Physical alarm buzzer

- Manual override switches

### 5. Communication

- Bluetooth module for mobile app connectivity

- Serial communication interfaces

# **Software Architecture**

## Android Application Structure

- User interface for appliance control

- Real-time temperature monitoring

- Door status logging system

- Bluetooth communication handler

- Alarm management system

## Microcontroller Firmware

- Main control loop

- Interrupt handlers for sensors

- Communication protocol implementation

- Safety monitoring routines

- State management system

## Communication Protocol

- Custom protocol over Bluetooth

- Command structure for device control

- Data formatting for sensor readings

- Error checking and recovery mechanisms

# **Software Implementation Details**

## Driver Layer Implementation

### 1. Utility Module (utils.h)

The system implements fundamental bitwise operations through macro definitions, These operations form the foundation for all hardware interactions in the system.

- **SET\_BIT:** Sets a specific bit in a register

**- CLEAR\_BIT:** Clears a specific bit in a register

**- TOGGLE\_BIT:** Toggles a specific bit in a register

**- GET\_BIT:** Reads the value of a specific bit

**- WRITE\_BYTE:** Writes a complete byte to a register

#ifndef BITWISE\_OPERATIONS\_H

#define BITWISE\_OPERATIONS\_H

#define SET\_BIT(REG, BIT) ((REG) |= (1U << (BIT)))

#define CLEAR\_BIT(REG, BIT) ((REG) &= ~(1U << (BIT)))

#define TOGGLE\_BIT(REG, BIT) ((REG) ^= (1U << (BIT)))

#define GET\_BIT(REG, BIT) (((REG) >> (BIT)) & 1U)

#define WRITE\_BYTE(REG, VALUE) ((REG) = VALUE))

#endif // BITWISE\_OPERATIONS\_H

## 2. Digital I/O Module (DIO)

The DIO module provides a hardware abstraction layer for **GPIO** operations:

**Key Features:**

- Port initialization and configuration

- Pin direction control (INPUT/OUTPUT)

- Digital/Analog mode selection

- Pull-up/Pull-down configuration

- Port and pin-level read/write operations

**Implementation Highlights:**

#include "DIO.h"

/\*\*

\* Function to get the base address of the specified port.

\* port: The port identifier (e.g., PORT\_A, PORT\_B, etc.).

\* return: The base address of the GPIO port, or 0xFF if the port is invalid.

\*/

uint32\_t get\_port\_base(uint8\_t port) {

switch (port) {

case PORT\_A: return GPIO\_PORTA\_BASE;

case PORT\_B: return GPIO\_PORTB\_BASE;

case PORT\_C: return GPIO\_PORTC\_BASE;

case PORT\_D: return GPIO\_PORTD\_BASE;

case PORT\_E: return GPIO\_PORTE\_BASE;

case PORT\_F: return GPIO\_PORTF\_BASE;

default: return 0xFF; // Invalid port identifier

}

}

/\*\*

\* Function to initialize a GPIO pin.

\* port: The port identifier (e.g., PORT\_A).

\* pin: The pin number within the port (0-7).

\* direction: The pin direction (1 for output, 0 for input).

\* mode: The mode of the pin (1 for digital, 0 for analog).

\*/

void dio\_init(uint8\_t port, uint8\_t pin, uint8\_t direction, uint8\_t mode) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return; // Exit if the port is invalid

// Enable the clock for the specified port

SET\_BIT(SYSCTL\_RCGCGPIO\_R, port);

while (GET\_BIT(SYSCTL\_PRGPIO\_R, port) == 0); // Wait until the port is ready

// Unlock mechanism for locked pins

GPIO\_PORT\_LOCK\_R(port\_base) = GPIO\_LOCK\_KEY; // Unlock the port using the key

SET\_BIT(GPIO\_PORT\_CR\_R(port\_base), pin); // Allow changes to the pin configuration

// Set the pin direction (input or output)

if (direction)

SET\_BIT(GPIO\_PORT\_DIR\_R(port\_base), pin); // Configure as output

else

CLEAR\_BIT(GPIO\_PORT\_DIR\_R(port\_base), pin); // Configure as input

// Configure the pin mode (digital or analog)

if (mode)

SET\_BIT(GPIO\_PORT\_DEN\_R(port\_base), pin); // Enable digital functionality

else

CLEAR\_BIT(GPIO\_PORT\_DEN\_R(port\_base), pin); // Enable analog functionality

}

/\*\*

\* Function to configure the internal pull-up resistor for a pin.

\* port: The port identifier (e.g., PORT\_A).

\* pin: The pin number within the port (0-7).

\* pull: Enable or disable pull-up (1 to enable, 0 to disable).

\*/

void dio\_pull(uint8\_t port, uint8\_t pin, uint8\_t pull) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return; // Exit if the port is invalid

if (pull)

SET\_BIT(GPIO\_PORT\_PUR\_R(port\_base), pin); // Enable pull-up resistor

else

CLEAR\_BIT(GPIO\_PORT\_PUR\_R(port\_base), pin); // Disable pull-up resistor

}

/\*\*

\* Function to read the value of a specific pin.

\* port: The port identifier (e.g., PORT\_A).

\* pin: The pin number within the port (0-7).

\* return: The value of the pin (1 for high, 0 for low, or 0xFF if invalid).

\*/

uint8\_t dio\_readpin(uint8\_t port, uint8\_t pin) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return 0xFF; // Return 0xFF for invalid port

return GET\_BIT(GPIO\_PORT\_DATA\_R(port\_base), pin); // Read and return pin value

}

/\*\*

\* Function to read the value of an entire port.

\* port: The port identifier (e.g., PORT\_A).

\* return: The value of the port (8-bit), or 0xFF if invalid.

\*/

uint8\_t dio\_readport(uint8\_t port) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return 0xFF; // Return 0xFF for invalid port

return (uint8\_t)GPIO\_PORT\_DATA\_R(port\_base); // Read and return port value

}

/\*\*

\* Function to write a value to a specific pin.

\* port: The port identifier (e.g., PORT\_A).

\* pin: The pin number within the port (0-7).

\* value: The value to write (1 for high, 0 for low).

\*/

void dio\_writepin(uint8\_t port, uint8\_t pin, uint8\_t value) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return; // Exit if the port is invalid

if (value)

SET\_BIT(GPIO\_PORT\_DATA\_R(port\_base), pin); // Set pin high

else

CLEAR\_BIT(GPIO\_PORT\_DATA\_R(port\_base), pin); // Set pin low

}

/\*\*

\* Function to write a value to an entire port.

\* port: The port identifier (e.g., PORT\_A).

\* value: The 8-bit value to write to the port.

\*/

void dio\_writeport(uint8\_t port, uint8\_t value) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return; // Exit if the port is invalid

GPIO\_PORT\_DATA\_R(port\_base) = value; // Write the value to the entire port

}

## 3. Door Control System

### Magnetic Switch Implementation:

#include "magnetic\_switch.h"

// Pointer to the interrupt callback function

static void (\*interrupt\_callback)(void) = 0; // Callback function for the interrupt

// Global variables to store the port and pin configuration

static uint8\_t g\_port;

static uint8\_t g\_pin;

/\*\*

\* Initialize the magnetic switch with the given port and pin.

\* Configures the pin as an input with a pull-up resistor and sets up the interrupt.

\* port: The GPIO port identifier (PORT\_B).

\* pin: The pin number within the port (4).

\* callback: Pointer to the callback function to execute on interrupt.

\*/

void magnetic\_switch\_init(uint8\_t port, uint8\_t pin, void (\*callback)(void)) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return; // Exit if the port is invalid

// Initialize the pin as input with pull-up resistor

dio\_init(port, pin, IN, DIGITAL);

dio\_pull(port, pin, UP);

// Store global interrupt configuration

g\_port = port;

g\_pin = pin;

// Configure GPIO interrupt settings

CLEAR\_BIT(GPIO\_PORT\_IM\_R(port\_base), pin); // Disable interrupt for the pin during setup

CLEAR\_BIT(GPIO\_PORT\_IS\_R(port\_base), pin); // Set to edge-sensitive interrupt

SET\_BIT(GPIO\_PORT\_IBE\_R(port\_base), pin); // Enable interrupt on both edges (rising and falling)

SET\_BIT(GPIO\_PORT\_ICR\_R(port\_base), pin); // Clear any prior interrupt flags

SET\_BIT(GPIO\_PORT\_IM\_R(port\_base), pin); // Enable interrupt for the pin

// Enable the corresponding NVIC interrupt for the port

switch (port) {

case PORT\_A: SET\_BIT(NVIC\_EN0\_R, 0); break;

case PORT\_B: SET\_BIT(NVIC\_EN0\_R, 1); break;

case PORT\_C: SET\_BIT(NVIC\_EN0\_R, 2); break;

case PORT\_D: SET\_BIT(NVIC\_EN0\_R, 3); break;

case PORT\_E: SET\_BIT(NVIC\_EN0\_R, 4); break;

case PORT\_F: SET\_BIT(NVIC\_EN0\_R, 30); break;

}

// Assign the user-defined callback function

interrupt\_callback = callback;

}

/\*\*

\* Get the current state of the magnetic switch.

\* port: The GPIO port identifier (e.g., PORT\_A).

\* pin: The pin number within the port (0-7).

\*return: The current state of the pin (1 for high, 0 for low, or 0xFF if invalid).

\*/

uint8\_t get\_magnetic\_switch\_state(uint8\_t port, uint8\_t pin) {

uint32\_t port\_base = get\_port\_base(port);

if (port\_base == 0xFF) return 0xFF; // Return 0xFF for invalid port

return dio\_readpin(port, pin); // Return the current state of the pin

}

/\*\*

\* Interrupt Service Routine (ISR) for the magnetic switch.

\* Handles the GPIO interrupt, clears the interrupt flag, and calls the user-defined callback function.

\*/

void magnetic\_switch\_handler(void) {

// Clear the interrupt flag for the specific pin

uint32\_t port\_base = get\_port\_base(g\_port);

if (port\_base == 0xFF) return; // Exit if port\_base is invalid

SET\_BIT(GPIO\_PORT\_ICR\_R(port\_base), g\_pin); // Clear the interrupt flag

// Execute the callback function if defined

if (interrupt\_callback != 0) {

interrupt\_callback(); // Call the user-defined interrupt handler

}

}

**Key Features:**

- Interrupt-driven door state detection

- Callback mechanism for state changes

- Built-in debouncing through hardware configuration

- Real-time status reporting through Bluetooth

## Hardware Abstraction Layer (HAL)