NED UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Formal Methods in Software Engineering

Formal Specification Document for

"HEV Radiator Controller System"

Group

- Bisma Shuja (SE-21024)
- Uzair Asif (SE-21032)

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HEV Radiator Controller System

1. Problem Statement: HEV Radiator Controller System

Background: A critical vehicle where a well-designed and effective radiator system is essential is a hybrid electric vehicle (HEV). In these vehicles, the thermal management system, which includes the radiator, is crucial for maintaining optimal operating temperatures for various components, especially the electric drivetrain components and the battery. To control the radiator system effectively, a software solution is required. The radiator system is equipped with a temperature sensor and a fan that can be activated or deactivated based on predefined temperature thresholds.

Requirements: Design and implement a software solution for controlling the vehicle radiator system. The system should be able to:

1. Set the temperature of the radiator system within valid bounds.
2. Activate the radiator fan when the temperature exceeds a specified maximum threshold.
3. Deactivate the radiator fan when the temperature goes below a specified minimum threshold.
4. Provide a mechanism to query the current status of the fan.

Specifications:

- The radiator system has a temperature sensor providing real-time temperature values.
- The fan should activate when the temperature exceeds a maximum limit of 80.0 degrees Celsius.
- The fan should deactivate when the temperature drops below a minimum limit of 20.0 degrees Celsius.
- Ensure that the temperature is within the valid bounds of 20.0 to 80.0 degrees Celsius.
- The system should prevent activating the fan if the temperature is below the minimum threshold and prevent deactivating the fan if the temperature is above the maximum threshold.
- Implement an enumeration (**Signal**) to represent the possible states of the fan (e.g., HIGH and LOW).

Functionalities:

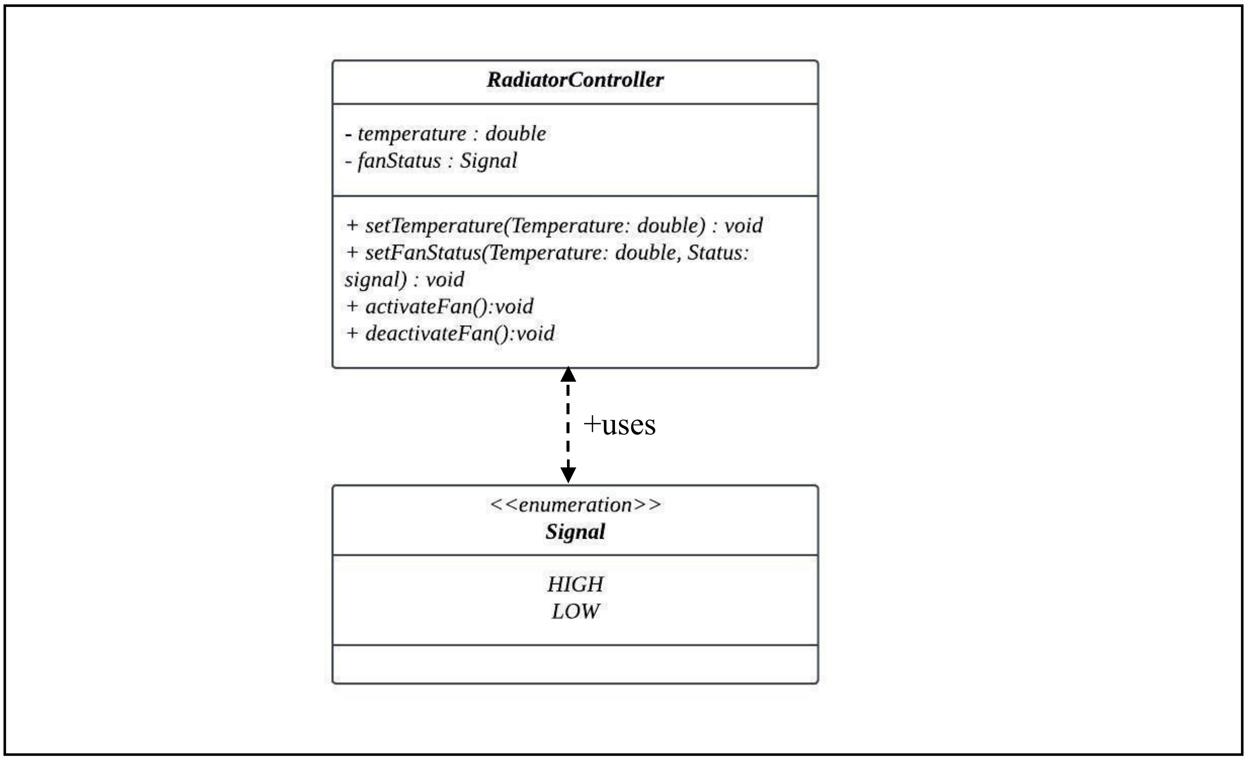
- **Set Temperature:**
    - Input: Temperature value.
    - Preconditions: The input temperature should be within the valid bounds.
    - Post conditions: The system temperature is updated, and the fan status is adjusted accordingly.
- **Set Fan Status:**
    - Preconditions: The current temperature should be within the valid bounds and not be null.
    - Post conditions: The fan status is set according to the current temperature.
- **Activate Fan:**
    - Preconditions: The current temperature is above the maximum threshold.
    - Post conditions: The fan is activated.
- **Deactivate Fan:**
    - Preconditions: The current temperature is below the minimum threshold.
    - Post conditions: The fan is deactivated.

Constraints:

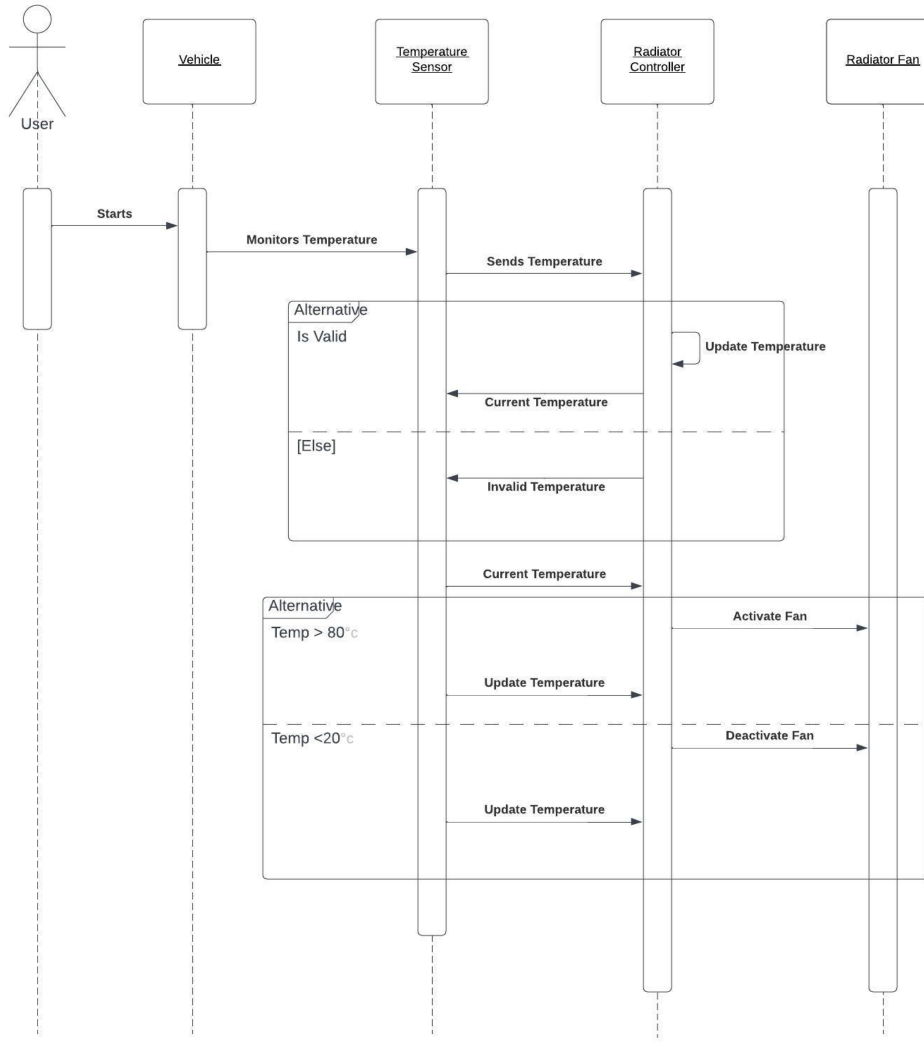
- Ensure the software adheres to the specified temperature thresholds and follows the pre and post-conditions for each operation.
- Implement proper error handling for invalid inputs and ensure the system maintains its invariants.

2. 4 + 1 Architectural View

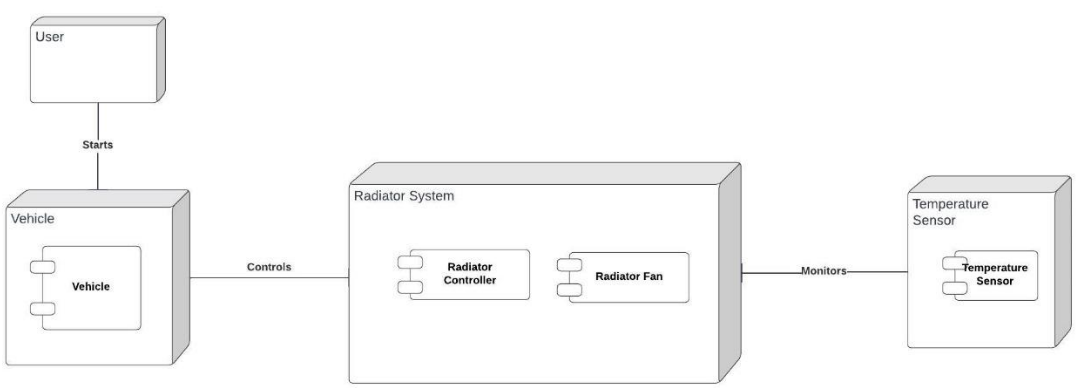
2.1. Logical View



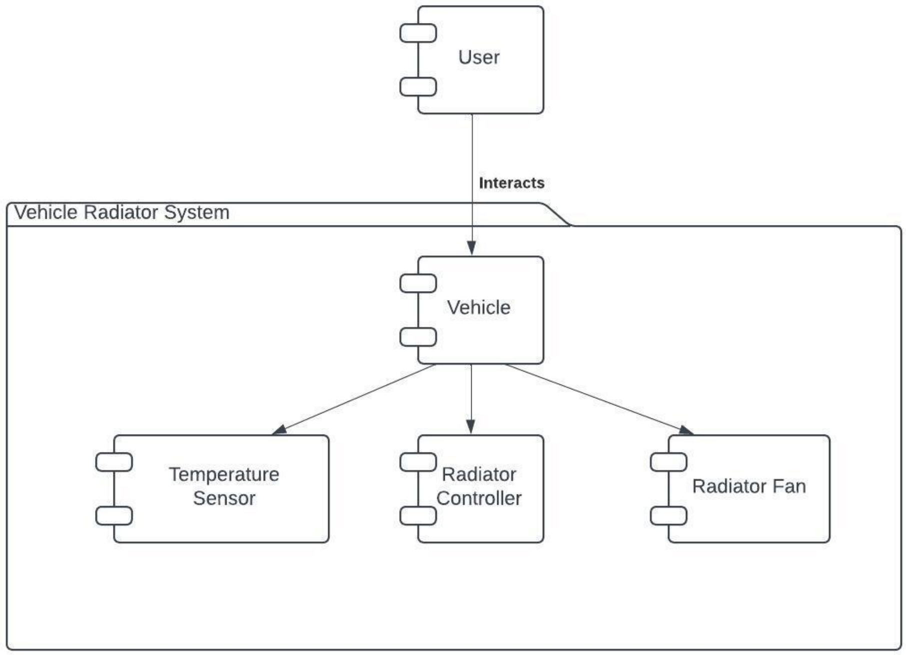
2.2. Process View



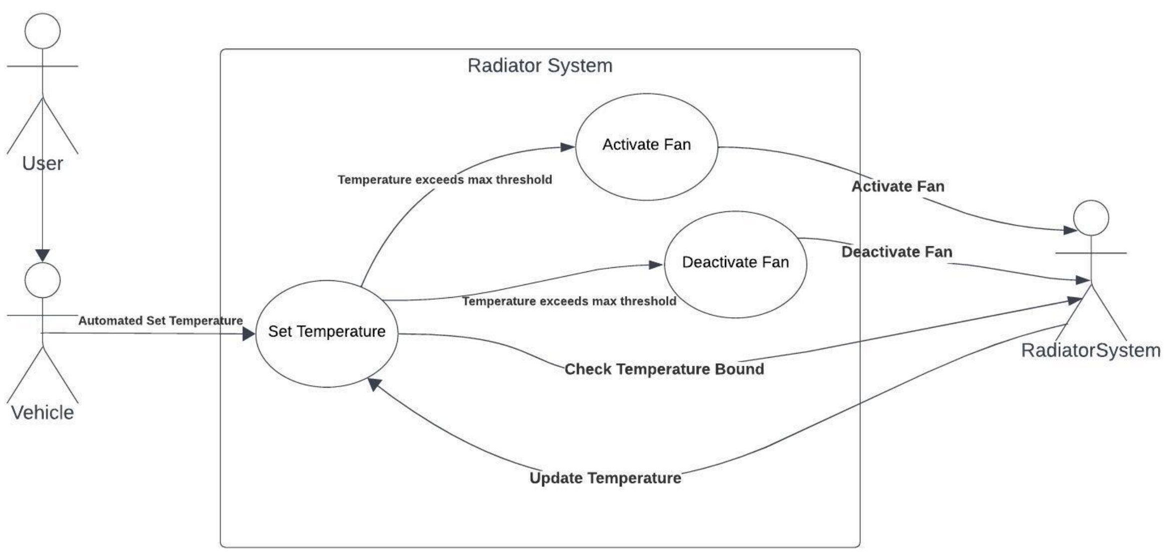
2.3. Physical View



2.4. Development View



2.5. +1 Scenarios



3. The complete specification of *RadiatorController* System

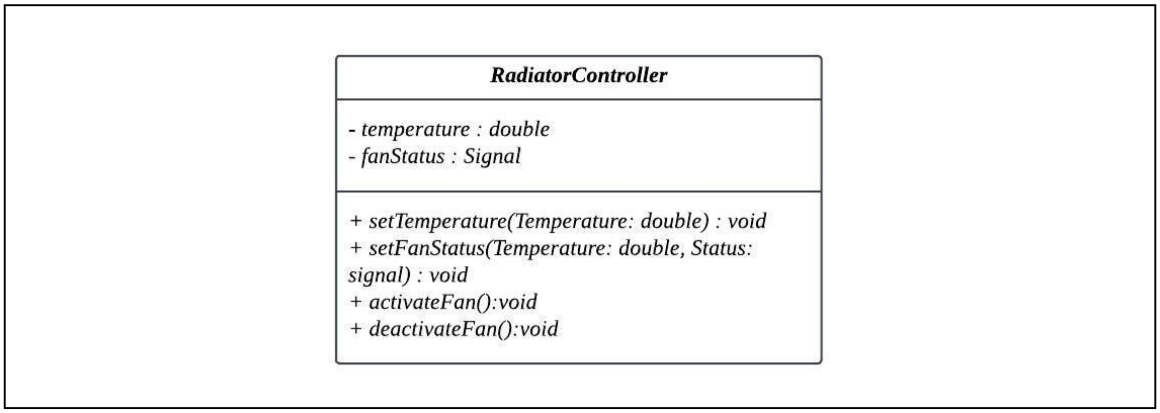


Figure 1 The specification of the *RadiatorController*

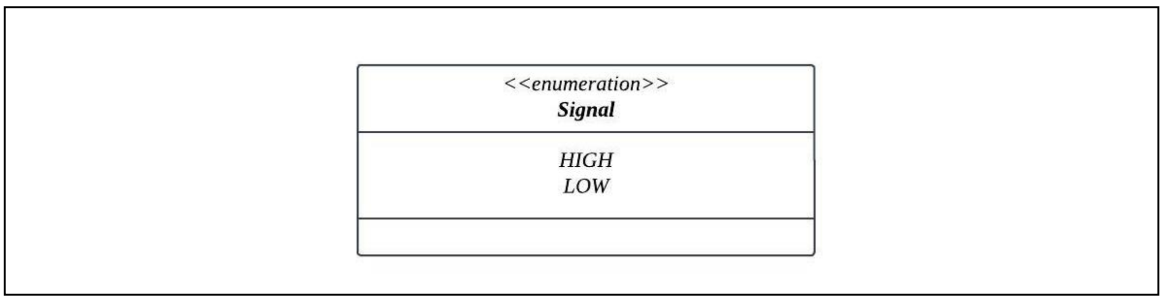


Figure 2 UML specification of the *Signal* type

```
types
  Temperature = ℝ;
  Signal = <HIGH> | <LOW>

values
  MIN_TEMPERATURE: Temperature = 20.0;
  MAX_TEMPERATURE: Temperature = 80.0;

state RadiatorController of
  temperature : [Temperature]
  fanStatus : [Signal]

  -- Temperature and fan status must be in range or equal to nil
  inv mk-RadiatorController (t, f) (inRange(t) ∨ = nil) ∧ (inRange(f) ∨ = nil)

  -- Temperature and fan status are undefined when the system is initialized
  init mk-RadiatorController (t, f) t = nil ∧ f = nil
end
```

```
functions
 inRange:(val: Temperature ) result: B
 pre True
 post  result ⇔ MIN_TEMPERATURE ≤ val  ≤ MAX_TEMPERATURE;

operations
– –an operation that sets the temperature of the system
 setTemperature: (temp : Temperature)
 ext  wr temperature:[Temperature]
 pre   inRange(temp) ∧ temperature = nil
 post  temperature = temp ∧ setFanStatus (temp, fanStatus);

– – an operation that records the temperature and signals the fan to high or low
 setFanStatus (temp:Temperature , status : Signal)
  ext rd temperature:[Temperature]
       wr fanStatus : [Signal]
  pre   inRange(temp) ∧  temperature ≠ nil
  post  ( temp ≥ MAX_TEMPERATURE ∧ activateFan() ) ∨ ( temp ≤
  MIN_TEMPERATURE ∧ deactiavteFan() )

– –an operation that changes the status of fan from low to high
activateFan()
  ext wr fanStatus : [Signal]
  pre fanStaus = <LOW>
  post fanStatus = <HIGH>

– –an operation that changes the status of fan from high to low
 deactivateFan()
 ext wr fanStatus : [Signal]
 pre fanStaus = <HIGH>
 post fanStatus = <LOW>
```

4. Java Implementation

Code:

```
// Enum for Signal
enum Signal {
    HIGH,
    LOW
}

// Class representing the state of RadiatorController
class RadiatorController {
    private Double temperature;
    private Signal fanStatus;

// Constructor
    public RadiatorController() {
        this.temperature = null;
        this.fanStatus = null;
    }

    // Invariant
    public boolean inRange(Double val) {
        return val != null && (val >= 20.0 && val <= 80.0);
    }

    // Initialization
    public RadiatorController(Double temp, Signal status) {
        assert inRange(temp) : "Temperature should be in the range or equal to
nil";
        assert status != null : "Fan status should be in the range or equal to
nil";
        this.temperature = temp;
        this.fanStatus = status;
    }

    // Function to set temperature
    public void setTemperature(Double temp) {
        assert inRange(temp) : "Temperature should be in the range or equal to
nil";
        assert temperature == null : "Temperature is already set";
        this.temperature = temp;
        setFanStatus(temp, fanStatus);
    }

    // Function to set fan status
```

```java
    private void setFanStatus(Double temp, Signal status) {
        assert inRange(temp) : "Temperature should be in the range or equal to 
nil";
        assert temperature != null : "Temperature should be set before setting 
fan status";

        if (temp >= 80.0) {
            activateFan();
        } else if (temp <= 20.0) {
            deactivateFan();
        }
    }

    // Function to activate fan
    private void activateFan() {
        assert fanStatus == Signal.LOW : "Fan is already activated";
        fanStatus = Signal.HIGH;
    }

    // Function to deactivate fan
    private void deactivateFan() {
        assert fanStatus == Signal.HIGH : "Fan is already deactivated";
        fanStatus = Signal.LOW;
    }

    // Getter for temperature
    public Double getTemperature() {
        return temperature;
    }

    // Getter for fan status
    public Signal getFanStatus() {
        return fanStatus;
    }
}

public class Main {
    public static void main(String[] args) {
        RadiatorController controller = new RadiatorController();

        // Example: Set temperature and print status
        Double temp = 100.0;
        controller.setTemperature(temp);
        printStatus(controller);
    }
```

```java
    private static void printStatus(RadiatorController controller) {
        System.out.println("Temperature: " + controller.getTemperature());

        if (controller.getTemperature() != null) {
            if (controller.getTemperature() >= 20.0 &&
controller.getTemperature() <= 80.0) {
                System.out.println("Fan Status: Normal");
            } else {
                System.out.println("Fan Status: " + controller.getFanStatus());
            }
        } else {
            System.out.println("Fan Status: Not available");
        }

        System.out.println();
    }
}
```

5. Testing Class

Code:

```
import java.util.Scanner;

class RadiatorControllerTest {
    public static void main(String[] args) {
        RadiatorController controller = new RadiatorController();
        Scanner scanner = new Scanner(System.in);

        int choice;
        do {
            System.out.println("");
            System.out.println("=== Radiator Controller Menu ===");
            System.out.println("1. Set Temperature");
            System.out.println("2. Print Status");
            System.out.println("0. Exit");
            System.out.print("Enter your choice: ");

            choice = scanner.nextInt();
            switch (choice) {
                case 1:
                    setTemperature(controller, scanner);
                    break;
                case 2:
                    printStatus(controller);
                    break;
                case 0:
                    System.out.println("Exiting the program. Goodbye!");
                    break;
                default:
                    System.out.println("Invalid choice. Please enter a valid
option.");
                    break;
            }

        } while (choice != 0);

        scanner.close();
    }
```

5.1. Output

```
User@DESKTOP-4PIM1JR MINGW64 /d/PROJECTS/A-05 FMS VDM (main)
$  /usr/bin/env C:\\Program\ Files\\Microsoft\\jdk-17.0.8.7-hot
4b8561e8b91623ac53d\\redhat.java\\jdt_ws\\A-05\ FMS\ VDM_c0e136

=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 2

=== Radiator Controller Status ===
Temperature: null
Fan Status: Not available


=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 1

Enter temperature: 10

=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 2

=== Radiator Controller Status ===
Temperature: 10.0
Fan Status: LOW


=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 1

Enter temperature: 50
```

```
=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 2

=== Radiator Controller Status ===
Temperature: 50.0
Fan Status: Normal


=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 1

Enter temperature: 110

=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 2

=== Radiator Controller Status ===
Temperature: 110.0
Fan Status: HIGH


=== Radiator Controller Menu ===
1. Set Temperature
2. Print Status
0. Exit
Enter your choice: 4
Invalid choice. Please enter a valid option.

 === Radiator Controller Menu ===
 1. Set Temperature
 2. Print Status
 0. Exit
 Enter your choice: 0
 Exiting the program. Goodbye!
```

5.2. Test Cases

Test Case Type	Description	Test Step	Expected Result	Status
Functionality	The system should perform three specified actions.	Record Temperature	Temperature to be recorded and checked against the specified thresholds.	PASS
		Print Status	Fan status to be displayed.	PASS
		Exit	Exit message should be displayed.	PASS
Validity	The system should not accept invalid inputs.	Enter any Invalid choice (other than 0,1,2).	Display Error Message	PASS
Correctness	The system should check for accuracy and correctness of data.	When the temperature is not set initially and status is inquired.	Fan Status: NOT AVAILABLE	PASS
		When the temperature is set less than 20 degrees Celsius and status is inquired.	Fan Status: LOW	PASS
		When the temperature is set equal or greater than 20 degrees and less than or equal to 80 degrees Celsius and status is inquired.	Fan Status: NORMAL	PASS
		When the temperature is set greater than 80 degrees Celsius and status is inquired.	Fan Status: HIGH	PASS

Github Repository Link: https://github.com/BismaShuja21/A-05-FMS-VDM.git