



## Certified LabVIEW Architect Examination

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Examinee \_\_\_\_\_ Date: \_\_\_\_\_

Administrator \_\_\_\_\_ Date: \_\_\_\_\_

### **Instructions:**

If you did not receive this exam in a sealed envelope stamped “NI Certification,” **DO NOT ACCEPT** this exam. Return it to the proctor immediately. You will be provided with a replacement exam.

- **Please do not detach the binding staple of any section. If any part of the exam paper is missing or detached when returned to National Instruments, you will be deemed to have failed the exam.**
- This examination may not be taken from the examination area or reproduced in any way. You may not keep any portion of this exam after you have completed it.
- Please do not ask the proctor for help. If you believe the intent of any part of the exam is not clear, you may make appropriate assumptions. Please document your assumptions on the LabVIEW block diagram of the appropriate VI.
- The exam requires you to architect a LabVIEW application based on a set of requirements.
- A computer with a standard installation of LabVIEW is the only reference allowed for the examination. Externally developed code and third party tools are not allowed in the exam.
- You may use LabVIEW design patterns, templates, and examples available in the development environment as a guide/resource for the application development.
- The application architecture must be specifically developed for the exam submission.
- Submit your LabVIEW application on the USB memory stick provided.
- Total time allocated for the exam: 4 hours
- Exam passing grade: 70%

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- By beginning work on the exam, you are accepting the NDA statement and agree not to disclose the content of this CLA Exam.

### **IMPORTANT:**

- **When you have completed the exam, place the exam document, the USB memory stick with the saved application, and any deliverables in the envelope provided.**
- **Please SEAL the envelope.**
- **Give the sealed envelope to your proctor.**

## **Section I: Project Deliverables**

For the purposes of this exam, you are required to design an architecture that covers all of the Project Specifications listed below. Your architecture should include implementations of the following key components:

- Project with hierarchy
- Main VI
- Shell (stub) modules and subVIs
- Interface for hardware
- Important data structures
- Inter-process communication mechanisms
- Application Programmers Interfaces (APIs) for all modules
- Error handling strategy
- Application shutdown strategy

Assume that specific algorithms, states, and functions will be implemented by a secondary developer. These do not need to be implemented as part of the test. However, for each requirement which is not implemented, you should include localized comments to a developer that describes a method for implementing the requirement.

### **Requirements Tracking**

In order to demonstrate coverage of a requirement, you must include the ID of the requirement in the documentation of your architecture. Each requirement's ID precedes the requirement text in the specification below. You may cover requirements in any part of your architecture's documentation, including:

- VI Documentation Property
- Control Documentation Property
- Project or Library Documentation Property
- Comments on the front panel or block diagram

A single requirement may be covered by multiple sections of code if all of those sections are necessary to fulfill the requirement.

To cover a requirement, include the following text in the documentation of your code:

[Covers: ID]

A requirement tracking tool is used to verify your program, therefore, please be careful to use this exact syntax. You should also double-check that each requirement ID is correct.

***The provided USB memory stick contains a text file that has all of the Tags. This file is provided as a convenience for use in placing the tags in the application code.***

### **Grading:**

The application architecture development exam consists of a total of 100 points which are allocated as follows:

- User interface and block diagram style : 10 points
- Documentation : 20 points
- Requirements coverage : 30 points
- Architecture development : 40 points

## **Project Specifications** **Car Wash Simulator**

### **Overview**

The car wash is a multi-station enclosure that a user can drive through to clean and dry the car exterior. The driver of the car begins at the entry of the car wash and selects wash options at the Entry Console before beginning the wash process.

The car wash enclosure has a series of stations where one or more car wash may be performed. Each station has a sensor that is activated by the presence of a vehicle and signals the controller to start one or more steps in the wash cycle and displays the progress on the display console. After completion of a car wash cycle, the controller should be ready to process another car.

### **Definitions**

**Simulation Interface** – A program which is run to test the Car Wash control algorithms in a software only environment. This program incorporates the Simulated Console, Simulated Database, and Car Wash Controller.

**Entry Console** – The interface via which the user selects the car wash options to be executed by the Car Wash Controller. All references to the Entry Console may apply to the Simulated Entry Console or Physical Entry Console.

**Physical Entry Console** – A hardware interface which includes the physical buttons and displays that allow a user to interact with the Car Wash Controller.

**Simulated Entry Console** – A software interface which mimics a Physical Console.

**Wash Display Console** – The interface via which the wash controller displays the progress of the car wash. All references to the Wash Display Console may apply to the Simulated Wash Display Console or Physical Wash Display Console.

**Physical Wash Display Console** – A hardware interface which includes the physical displays that allow a user to monitor the progress of the wash.

**Simulated Wash Display Console** – A software interface which mimics a Physical Console.

**Vehicle Position Interface** – The interface via which the user is able to simulate the travel of a vehicle in the car wash enclosure during a wash cycle. All references to the Vehicle Position Simulation may apply to the Simulated Vehicle Position Simulation or the Hardware Interface that will communicate the vehicle position information to the controller.

**Hardware Interface** – the computer interface which includes the physical sensors and the data acquisition device.

**Vehicle Position Simulation** – A software interface which mimics the hardware interfaces that communicate the vehicle position.

**Configuration Database** – The interface by which the Car Wash Controller accesses configuration data for the wash steps. All references to the Configuration Database may apply to the Embedded Configuration Database or Simulated Configuration Database.

**Embedded Configuration Database** – A database which provides timing and other wash step related data to the Car Wash Controller.

**Simulated Configuration Database** – A software interface which mimics access to an Embedded Configuration Database.

**Car Wash Controller** – The software that manages the wash steps and functions for the Car Wash.

**Car Wash Cycle** – A wash cycle is initiated when the user selects the wash options and presses the Start button. It is complete when the last step is complete and the car exits from the car wash enclosure.

## **Simulation Interface**

Due to the unavailability of a physical setup, your client has requested that you create simulations of consoles and external hardware. These simulations will be used to validate the Car Wash controller logic and algorithms.

The Simulated Consoles will be replaced with a prototype Physical Consoles in a subsequent project phase and the Vehicle Position Simulation will be replaced with sensor data from data acquisition hardware interfaces.

The Simulated Database will be replaced with an embedded database in a subsequent project phase.

### **Simulation Interface Requirements**

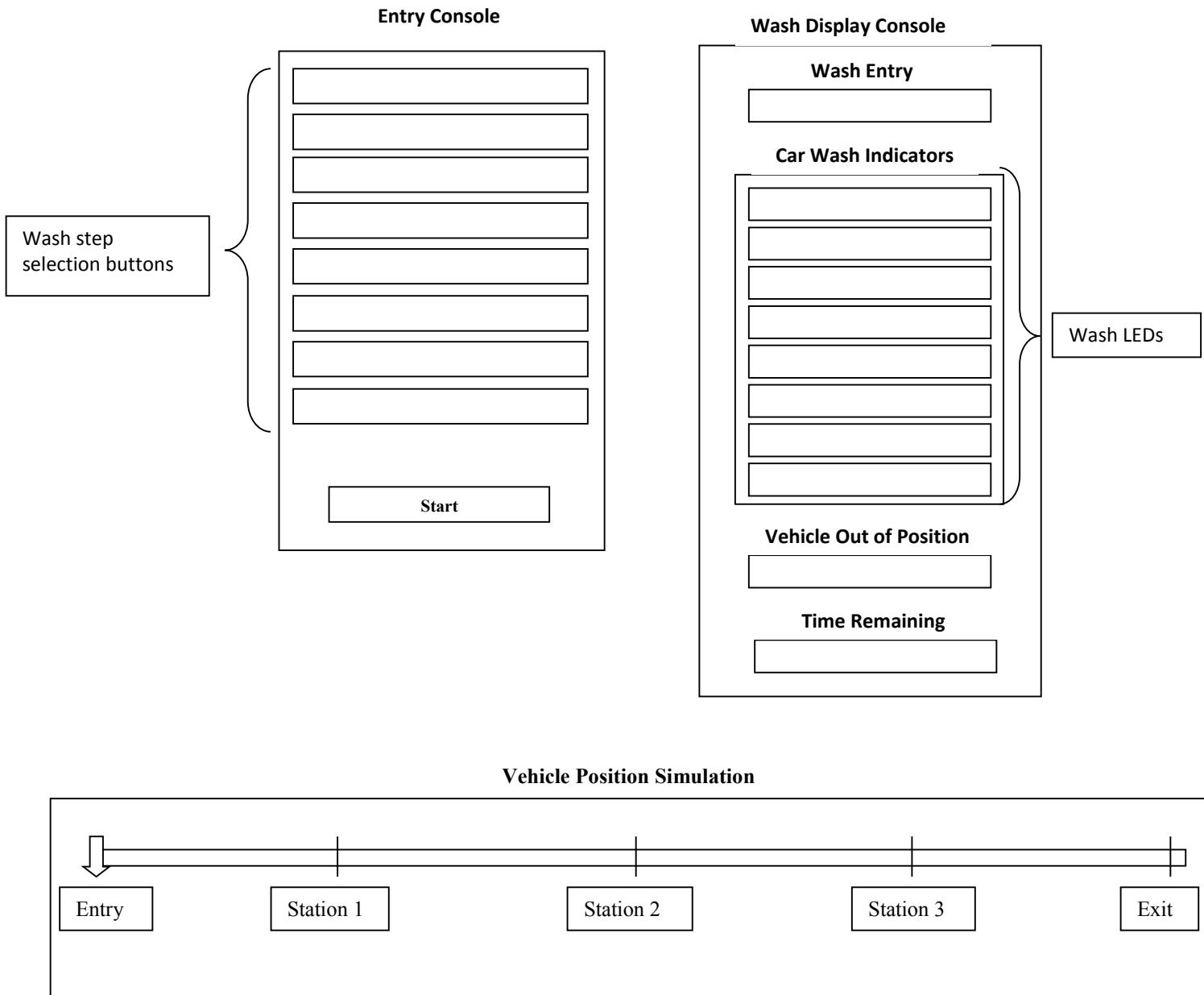
SI1. The components of the Simulation Interface shall be separated from the Car Wash controller by defined interfaces which mimic communication with the Physical Consoles, Vehicle Position hardware and the Embedded Database.

SI2. The Simulation Interface shall automatically initiate the Simulated Consoles (Entry and Wash Display) Vehicle Position, Simulated Database, and Car Wash Controller upon startup.

SI3. The Simulation Interface simulates a single wash cycle and terminates when the controller completes the wash steps and the car exits the wash enclosure.

**Simulated Console Requirements**

Your client has given you the following illustration of the Car Wash consoles and Vehicle Position simulation



UI1. The simulated consoles shall mimic the illustrations as closely as possible. The simulated interface shall include the following:

- Entry Console
- Wash Display Console
- Vehicle Position Simulation

UI2. The **Entry Console** shall consist of the following components:

UI2A. **Wash steps selection buttons.** The buttons shall be labeled to represent the wash functions from top to bottom as listed:

- Under Body Wash
- Bug Remover
- Pre-Soak
- High Pressure Wash (default)
- Low Pressure Wax
- Spot Free Rinse
- Tire Shine Foam
- Air Dry

UI2A1. The Wash step buttons shall be pressed by user to select the wash steps before starting the wash.

UI2A2. The Wash step buttons shall remain in the pressed state until the wash completes. On completion of the wash (signaled by the vehicle exiting the wash enclosure) the buttons shall be restored to the original state.

UI2A3. The Wash step buttons shall be disabled when the car wash operation begins.

UI2A4. The Wash step buttons shall be enabled on completion of the wash.

UI2B. **Wash Start button.** This button shall be labeled Start Wash.

UI2B1. Pressing the Wash Start button shall start the car wash operation.

UI3. The **Wash Display Console** shall consist of the following components:

UI3A. **Wash Entry display** component shall notify the users if the wash is currently in progress.

UI3A1. The Wash Entry Display shall display the following text, initiated by the Car Wash Controller:

- Wash Vacant: Displays when no car is being washed.
- Wash In Progress: Displays when a car is in the car wash and a wash operation is in progress.

UI3A2. While Wash Vacant is being displayed, the background color of the display shall be Green.

UI3A3. While Wash in Progress is being displayed, the background color of the display shall be Red.

UI3B. **Car Wash Indicators** component shall consist of an LED array that correspond the car wash step.

UI3B1. Each indicator shall be labeled with the text of the corresponding wash step.

- UI3B2. All indicators shall be initialized to OFF when the Car Wash Controller starts up and when a wash cycle completes.
- UI3B3. The appropriate indicator for the step shall turn ON when the car is in the correct station and the wash step is being executed.
- UI3B4. The indicator will remain ON until the wash step is complete.
- UI3B5. The indicator shall turn OFF when the wash step completes.
- UI3C. **Vehicle Out of Position** indicator component shall consist of a two color LED that shall indicate if the car is at the designated Station for the wash operation.
  - UI3C1. The indicator will indicate Red if the car is not in the appropriate station or has moved away from the station.
  - UI3C2. The indicator will indicate Green if the vehicle is in the appropriate station.
- UI3D. **Time Remaining** indicator component shall display the time remaining for the current wash to finish.
  - UI3D1. The time shall be formatted as xxxx.xx Seconds
  - UI3D2. The indicator shall initialize to the step time set in the Simulated Configuration Database.
  - UI3D3. The indicator shall count down from the set time to zero while the Car Wash controller is executing the wash step.
  - UI3D4. The indicator shall pause the timing if the car moves away from the station during step execution.
- UI4. The Vehicle Position Simulation shall be used to simulate the travel of the car through the enclosure by activating Station sensors.
  - UI4A. Each position of the simulation shall correspond to a wash station in the wash enclosure.
  - UI4B. The following table lists the wash steps that shall be executed at a particular station.

| Station   | Wash Step                    | Step Timing |
|-----------|------------------------------|-------------|
| Entry     | None                         | N/A         |
| Station 1 | Under Body Wash              | 30 seconds  |
|           | Bug Remover                  | 20 seconds  |
| Station 2 | Pre-Soak                     | 50 seconds  |
|           | High Pressure Wash (default) | 60 seconds  |
|           | Low Pressure Wax             | 45 seconds  |
|           | Spot Free Rinse              | 50 seconds  |
| Station 3 | Tire Shine Foam              | 45 seconds  |
|           | Air Dry                      | 50 seconds  |
| Exit      | None                         | N/A         |

### **Configuration Database Requirements**

**SD1.** The database shall store records where each record contains the following elements.

**SD1A.** Wash Step – Text, maximum of 256 characters

**SD1B.** Station – Text, maximum of 256 characters

**SD1C.** Step Duration – 5 digit integer number. Step timing data is provided in requirement UI4B above.



**Note** The above descriptions merely describe the type and limits of each element. You may choose to store and/or implement each element with any data type that meets the requirements.

**SD2.** The design shall include a Default Configuration Database and a Client Configuration Database.

**SD3.** The controller shall read the Client Configuration Database on startup and store the information in an appropriate data structure.

**SD4.** If the Client Configuration Database is not found, the controller shall read and Default Configuration Database.

**SD5.** A database interface shall be provided to read records, query timing data, insert new data records and update data records.

**SD6.** A separate user interface shall be provided to full access to the data records. The integration of the user interface in the main application will be done in future project.

**SD7.** The database interface shall provide a database locking mechanism to ensure that the database is accessible from one source only.

### **Car Wash Controller**

The Car Wash Controller is the software component that allows the user to interact with the controls and provides appropriate feedback as requested through the display console. The Car Wash Controller performs the following main functions:

- Read the Configuration database to get timing data
- Get the selected wash options from the Entry console
- Start the washing process when user presses the Start button
- Get vehicle position data and execute the wash function
- Update the Wash Display console



**Note** The operation of the machine is described in states. This is a convenient and descriptive format for showing the order of operations and response to inputs and is not intended to constrain the architecture to any specific design, logic, or states.

### **Initial State Requirements**

**IS1.** Entry Console:

**IS1A.** Enable all wash steps selection buttons. Any buttons pressed from a previous wash cycle should be released.

**IS1B.** Enable the Start button and ensure it is in the OFF state.

**IS2.** Wash Display Console:

**IS2A.** The Wash Entry indicator shall display Wash Vacant.

**IS2B.** The Car Wash indicators shall be OFF.



- IS2C. Vehicle Out of Position indicator shall be Red.
- IS2D. Time Remaining Indicator shall be 0.00
- IS3. Vehicle Position Simulation control shall be initialized with the vehicle at the entry position.
- IS4. Read Configuration Database and initialize data structures with Wash step timing data.

**Wait for Start State Requirements**

- WS1. Maintain Initial State Requirements.
- WS2. Allow to user to select wash steps using the wash steps selection buttons on the Entry Console.
  - WS2A. The wash step selection button shall remain pressed until the wash cycle is completed.
- WS3. Wait for user to press the Start button.

**Start State Requirements**

- SS1. Disable the Entry Console controls.
- SS2. The Wash Entry indicator shall display Wash In Progress.
- SS3. Process wash steps selection buttons.
  - SS3A. If the user does not select the High Pressure Wash step, or if the user did not select any steps, the High Pressure Wash step shall be added to the steps.
- SS4. Vehicle Out of Position indicator shall be Red.
- SS5. The Car Wash indicator corresponding to the first wash step (from the selected steps) shall turn ON.
- SS6. Time Remaining indicator shall initialize to the time for the wash step.

**Wait for Vehicle Position State Requirements**

- VS1. The Car Wash indicator corresponding to the wash step shall be ON.
- VS2. Vehicle Out of Position indicator shall be Red.
- VS3. Time Remaining indicator shall display the time remaining for the wash step.
- VS4. Wait for user to move the car position to the station that serves the currently active wash step or Exit if the step was the last step in the wash cycle

**Wash Step Execution State Requirements**

- WX1. For the wash step to execute, the car shall be on the station that serves the currently active wash step.
- WX2. The Car Wash indicator corresponding to the wash step shall be ON
- WX3. Vehicle Out of Position indicator shall be Green.
- WX4. Time Remaining indicator shall count down to zero to indicate the time remaining for the wash step to complete.

### **Wash Step / Cycle Completion State Requirements**

- WC1. The Car Wash indicator corresponding to the completed wash step shall turn OFF
- WC2. If the wash step that completed execution was the last step.
  - WC2A. All Car Wash indicators shall be OFF.
  - WC2B. Vehicle Out of Position indicator shall be Red.
  - WC2C. Wait for user to move the car position to the Exit position.
- WC3. If the wash step that completed execution was not the last step.
  - WC3A. The Car Wash indicator corresponding to the next wash step shall turn ON
  - WC3B. Vehicle Out of Position indicator shall be Red.
  - WC3C. Wait for user to move the car position to the station that serves the currently active wash.

### **Wash Exit State Requirements**

- WE1. The Car Wash indicators shall turn OFF.
- WE2. Wait for user to move car position to the Exit position.
- WE3. On moving to Exit position, controller shall reposition the vehicle position to the Entry position.
- WE4. Controller shall initialize all displays to Initial State Requirements.

### **Wash Abort /Terminate State Requirements**

- TS1. All components of the Entry Console shall be disabled.
- TS2. The current executing step shall be aborted.
- TS3. The Car Wash indicators shall turn OFF.
- TS4. Vehicle Out of Position indicator shall be Red.
- TS5. Time Remaining indicator shall display 0.00
- TS6. Display Error Dialog with message for user to move car to the exit position

### **Error Handling Requirements**

- EH1. The system shall define three levels of error with associated actions.
  - EH1A. A Minor Error shall be invisible to the user. The system should continue any operations without interruption.
  - EH1B. A Wash Cycle Error will cause the system to enter the Wash Abort /Terminate state.
    - EH1B1. The controller shall display an Error Dialog with message for user to move car to the Exit position.
    - EH1B2. The controller shall ready itself to run a new wash cycle.
  - EH1C. A System Error shall lock out the system and cause the system to enter the Wash Abort / Terminate state.
    - EH1C1. A system error shall cause a shutdown of all consoles and hardware
    - EH1C2. The controller shall display an Error Dialog with message for user to move car to the Exit position.
    - EH1C3. The controller shall terminate the application.
- EH2. The error handling system shall maintain a log file which can be checked by Car Wash maintenance personnel.
  - EH2A. The error log shall include a description of each error that occurs.
  - EH2B. The error log shall include the level of the error, as specified by EH1.

EH2C. The error log shall include the time and date at which the error occurred.

EH2D. The error log shall include the station and step at the time the error occurred.



**Note** When an error level is not specifically noted in this document, the system designer shall select the appropriate error level based upon the impact of the error.

The system designer may, at their discretion, ignore errors that are expected behavior or errors that are entirely handled by the system. Such errors do not need to be noted in the error log.