Functional Specification Document: Roundabout Traffic Light Controller

Document Control

Version	Date	Author	Changes
1.0	2023-10-27	Philip O. Ayomipo	Final draft based on completed and tested PLC/HMI project.

1.0 Introduction

- **1.1 Purpose:** This document defines the functional requirements for a PLC and HMI system designed to simulate and control a standard four-way roundabout intersection. It details the control logic, operational sequences, and the Human-Machine Interface (HMI) for system monitoring and control.
- **1.2 Scope:** The system controls the traffic flow for four approaches (North, South, East, West) to a central roundabout. Each approach is equipped with a three-light signal (Red, Yellow, Green). The system operates on a timed sequence to ensure safe passage of traffic. Pedestrian crosswalks, vehicle detection, and HMI-based parameter adjustment are outside the scope of this project.
- **1.3 References:**
  - Roundabout_Layout.png
  - TIA Portal Project: Traffic light controller

2.0 System Architecture

- **2.1 Hardware Overview:**
  - **PLC:** Siemens SIMATIC S7-1500 (Simulated: CPU 1511C-1 PN)
  - **HMI:** Siemens SIMATIC Comfort Panel (Simulated: TP700 Comfort via WinCC Runtime Advanced)
  - **Network:** Profinet/IE connection between PLC and HMI.
  - **Simulation Environment:** PLCSIM V18
- **2.2 Software Overview:**
  - **Programming Environment:** Siemens TIA Portal V18

3.0 System Operational Modes

The system operates in two primary modes, controlled via an interactive element on the HMI.

- **3.1 System Off (All Red State):**
  - **Condition:** This is the default state of the system on initial power-up or when the system is stopped via the HMI. The Enable input to the main control block is FALSE.
  - **Behavior:** The control sequence is reset to its initial step. All traffic lights for all four directions are commanded to be **RED**. The HMI displays a “Not active” status.
- **3.2 Normal Operation (Automatic Cycle):**

- **Condition:** Activated when the central circle on the HMI is pressed while the system is in the "Off" state. This action toggles the Enable input to the main control block to TRUE.
- **Behavior:** The system begins executing the timed traffic light sequence. The HMI displays an "Active" status. The system will continue to cycle through the sequence until it is stopped by pressing the central HMI circle again.

4.0 PLC Functional Description

- **4.1 Program Structure:**
  - **OB1 (Main):** The main program cycle contains the call to the primary Function Block Traffic_Light_Sequencer [FB1]. It maps the block's outputs to the physical PLC outputs.
  - **Traffic_Light_Sequencer [FB1]:** This reusable block contains the entire state machine logic. It uses an integer tag (Step_Number) to track the current state and TON timers to control the duration of each state.
  - **Traffic_Light_Sequencer_DB [DB13]:** The instance Data Block for FB1, which stores all static and output data for the sequencer, including the current step number and hard-coded timer presets.
- **4.2 PLC-HMI Interface Data (within Traffic_Light_Sequencer_DB):**

Static Tag	Data Type	Start Value	Description
Enable	Bool	false	HMI command to start/stop the sequence. Toggled by the HMI.
Step_Number	Int	0	Stores the active step number of the sequence.
System_Active	Bool	false	Internal status indicating if the sequence is running. Used for HMI feedback.
Yellow timer pt	Time	T#7s	Preset time for Yellow light duration.
Green timer pt	Time	T#10s	Preset time for Green light duration.
Red timer pt	Time	T#3ms	Preset time for the "All Red" transition delay between main sequences.

- **4.3 Control Sequence Logic:** The core of the system is a state machine driven by the Step_Number tag. The sequence is advanced by a series of timers corresponding to each state. When a timer for the current state expires, a MOVE instruction updates the Step_Number tag to the next state in the sequence. The light outputs are commanded based on the active Step_Number.

- **4.4 Functional Sequence of Operation:** The system cycles through the four directions, following a standard Green -> Yellow -> Red pattern with a safe "All Red" period between directional changes.

Event	Active Lights	Duration	Condition to Advance
HMI Start	**ALL DIRECTIONS: RED** -> N: **GREEN**,	-	System_Active = TRUE

Event	Active Lights	Duration	Condition to Advance
	S/E/W: **RED**		
1. North Green	N: **GREEN**, S/E/W: **RED**	Green timer pt (10s)	North Green Timer Expires
2. North Yellow	N: **YELLOW**, S/E/W: **RED**	Yellow timer pt (7s)	North Yellow Timer Expires
3. All Red Delay	**ALL DIRECTIONS: RED**	Red timer pt (3ms)	All Red Timer Expires
4. East Green	E: **GREEN**, N/S/W: **RED**	Green timer pt (10s)	East Green Timer Expires
5. East Yellow	E: **YELLOW**, N/S/W: **RED**	Yellow timer pt (7s)	East Yellow Timer Expires
6. All Red Delay	**ALL DIRECTIONS: RED**	Red timer pt (3ms)	All Red Timer Expires
7. South Green	S: **GREEN**, N/E/W: **RED**	Green timer pt (10s)	South Green Timer Expires
8. South Yellow	S: **YELLOW**, N/E/W: **RED**	Yellow timer pt (7s)	South Yellow Timer Expires
9. All Red Delay	**ALL DIRECTIONS: RED**	Red timer pt (3ms)	All Red Timer Expires
10. West Green	W: **GREEN**, N/S/E: **RED**	Green timer pt (10s)	West Green Timer Expires
11. West Yellow	W: **YELLOW**, N/S/E: **RED**	Yellow timer pt (7s)	West Yellow Timer Expires
12. All Red Delay	**ALL DIRECTIONS: RED**	Red timer pt (3ms)	All Red Timer Expires **(Cycle returns to Event 1)**

5.0 HMI Functional Description

- **5.1 Screen Overview:** The HMI utilizes a single “Root screen” for all system visualization and control.
- **5.2 Screen 1: Main Control & Overview**
  - **Screen Image:**
  - **Purpose:** To provide a real-time visual representation of the intersection, allow for system start/stop control, and display the current system status.
  - **HMI Objects and Behavior:**

Object	Type	Action / Behavior
Central Display	Texts (12 total)	The visibility of each Text is animated based on the

		corresponding PLC boolean tag (e.g., the North text (green color) is visible when North_Green is TRUE).
Status Indicator	Text Field / Rectangle	Displays “Not active” with a red background when the system is stopped. Displays “Active” with a green background when the sequence is running.
Traffic Light Indicators	Circles (12 total)	The appearance of each circle is animated based on the corresponding PLC boolean tag (e.g., the North Green circle is Green when North_Green is TRUE).

- **5.3 HMI Tag Table:**

HMI Tag Name	PLC Tag Connection
EGREEN	Traffic_Light_Sequencer_DB.East_Green
Enable	Traffic_Light_Sequencer_DB.Enable
ERED	Traffic_Light_Sequencer_DB.East_Red
EYELLOW	Traffic_Light_Sequencer_DB.East_Yellow
NGREEN	Traffic_Light_Sequencer_DB.North_Green
NRED	Traffic_Light_Sequencer_DB.North_Red
NYELLOW	Traffic_Light_Sequencer_DB.North_Yellow
SGREEN	Traffic_Light_Sequencer_DB.South_Green
SRED	Traffic_Light_Sequencer_DB.South_Red
SYELLOW	Traffic_Light_Sequencer_DB.South_Yellow
System_Active	Traffic_Light_Sequencer_DB.System_Active
WGREEN	Traffic_Light_Sequencer_DB.West_Green
WRED	Traffic_Light_Sequencer_DB.West_Red
WYELLOW	Traffic_Light_Sequencer_DB.West_Yellow