Objective:

Design and implement a PLC-based automated parking management system to efficiently manage limited spaces, optimize traffic flow, and enhance user experience while promoting sustainability and security.

Interface:

The interface consists of:

Physical inputs

No	Symbol	Function	Lock	Parameters	Location of (L/C)	Comment
I1		Discrete inputs	---	No parameters	(1/1)	In_Before
I2		Discrete inputs	---	No parameters	(8/1) (9/2) (11/4)	In_At
I3		Discrete inputs	---	No parameters	(1/2) (9/3)	In_After
I4		Discrete inputs	---	No parameters	(3/3) (4/3)	In_Teacher
I5		Discrete inputs	---	No parameters	(3/4) (4/4)	In_Student
I7		Discrete inputs	---	No parameters	(14/2)	Out_Before
I8		Discrete inputs	---	No parameters	(19/1) (20/3) (22/4)	Out_At
I9		Discrete inputs	---	No parameters	(14/1) (20/1)	Out_After
IA		Discrete inputs	---	No parameters	(14/3) (15/4)	Out_Teacher
IB		Discrete inputs	---	No parameters	(14/4) (15/3)	Out_Student
ID		Discrete inputs	---	No parameters	(2/3)	Override

Module keys

No	Symbol	Function	Location of (L/C)	Comment
Z1		Zx keys	(37/1)	

Physical outputs

No	Symbol	Function	Latching	Location of (L/C)	Comment
Q1		Discrete outputs	No	(7/6) (8/6)	In_Gate
Q2		Discrete outputs	No	(18/6) (19/6)	Exit_Gate
Q3		Discrete outputs	No	(34/6)	Teacher_Max
Q4		Discrete outputs	No	(35/6)	Student_Max

Text block

X1		Text blocks	DisplayScreen

	_	C	1	_	C	/	3		T	e	a	c	h	e	r	s	
	_	C	2	_	C	/	4		S	t	u	d	e	n	t	s	

☐ Modification authorized in L2C2
☐ Modification authorized in L3C2

Configurable functions

No	Symbol	Function	Lock	Latching	Parameters	Location of (L/C)	Comment
C1		Counters	No	No	Value to attain: 3 Pulses Output ON when the preset value is reached	(3/5) (25/6) (26/6) (34/1) (37/6)	Counter_Teacher
C2		Counters	No	No	Value to attain: 4 Pulses Output ON when the preset value is reached	(4/5) (29/6) (30/6) (35/1) (38/6)	Counter_Student
H1		Clocks	No	---	See details below	(1/3)	
N1		Auxiliary relays	---	No	No parameters	(1/6) (3/2)	init
N2		Auxiliary relays	---	No	No parameters	(3/6) (5/1) (8/2) (9/4) (10/5) (11/6) (12/1)	inT
N3		Auxiliary relays	---	No	No parameters	(4/6) (6/1) (7/2) (9/5) (10/4) (11/1) (12/6)	inS
N4		Auxiliary relays	---	No	No parameters	(9/6) (12/2) (25/2) (26/2) (27/2) (28/6)	Tin
N5		Auxiliary relays	---	No	No parameters	(10/6) (13/2) (29/2) (30/2) (31/2) (32/6)	Sin
N6		Auxiliary relays	---	No	No parameters	(14/6) (16/1) (19/2) (20/4) (21/5) (22/6) (23/1)	outT
N7		Auxiliary relays	---	No	No parameters	(15/6) (17/1) (18/2) (20/5) (21/4) (22/1) (23/6)	outS
N8		Auxiliary relays	---	No	No parameters	(20/6) (24/2) (25/1) (26/1) (27/1) (27/6)	Tout
N9		Auxiliary relays	---	No	No parameters	(21/6) (23/2) (29/1) (30/1) (31/1) (31/6)	Sout
T1		Timers	No	No	See details below	(5/6) (7/1) (11/2)	
T2		Timers	No	No	See details below	(16/6) (18/1) (22/2)	
X1		Text blocks	---	---	See details below	(33/6)	DisplayScreen

Clock

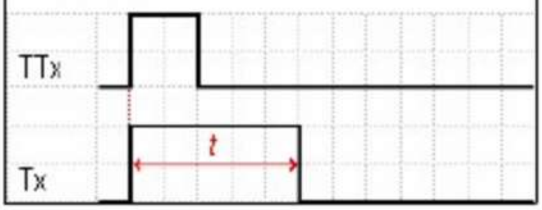
H1 Clocks

Weekly :
Channel A, ON, MON TUE WEDS THURS FRI , 07:30.
Channel A, OFF, MON TUE WEDS THURS FRI , 22:00.
Channel B, ON, SAT SUN , 14:00.
Channel B, OFF, SAT SUN , 22:00.
Channel C, ON, , 00:00.
Channel C, OFF, , 00:00.
Channel D, ON, , 00:00.
Channel D, OFF, , 00:00.

Timer

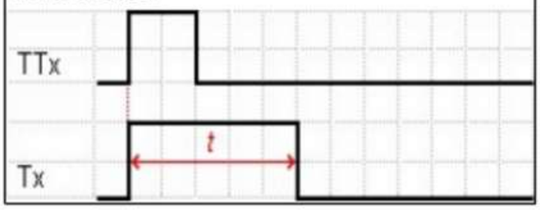
T1 Timers

Function B: On pulse one shot
Time: 010.0 s

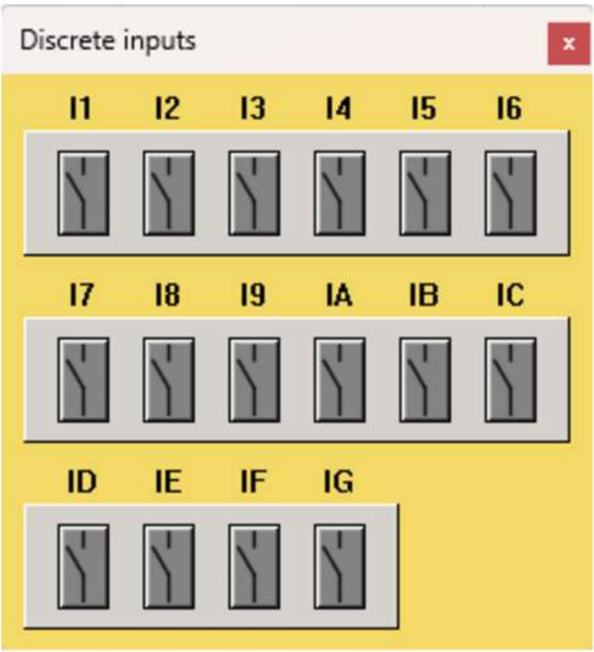


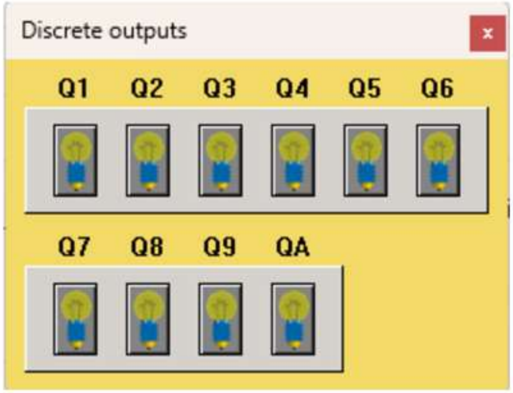
T2 Timers

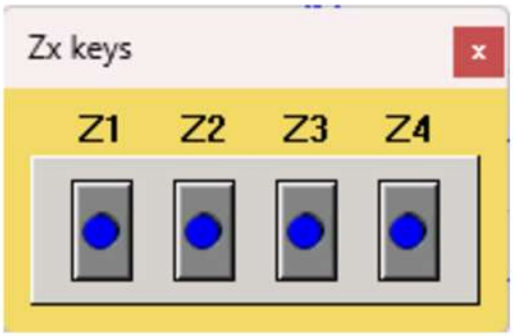
Function B: On pulse one shot
Time: 010.0 s



In the simulation, every input is depicted as a switch, and each output is symbolized by a light bulb. The push button is characterized as Zx Keys. Similarly, counter values and coil states are illustrated below.

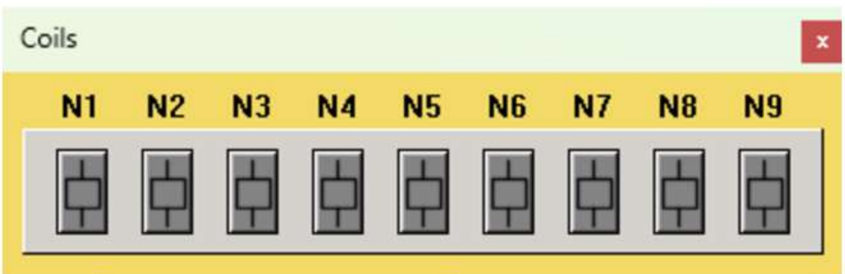






Function blocks

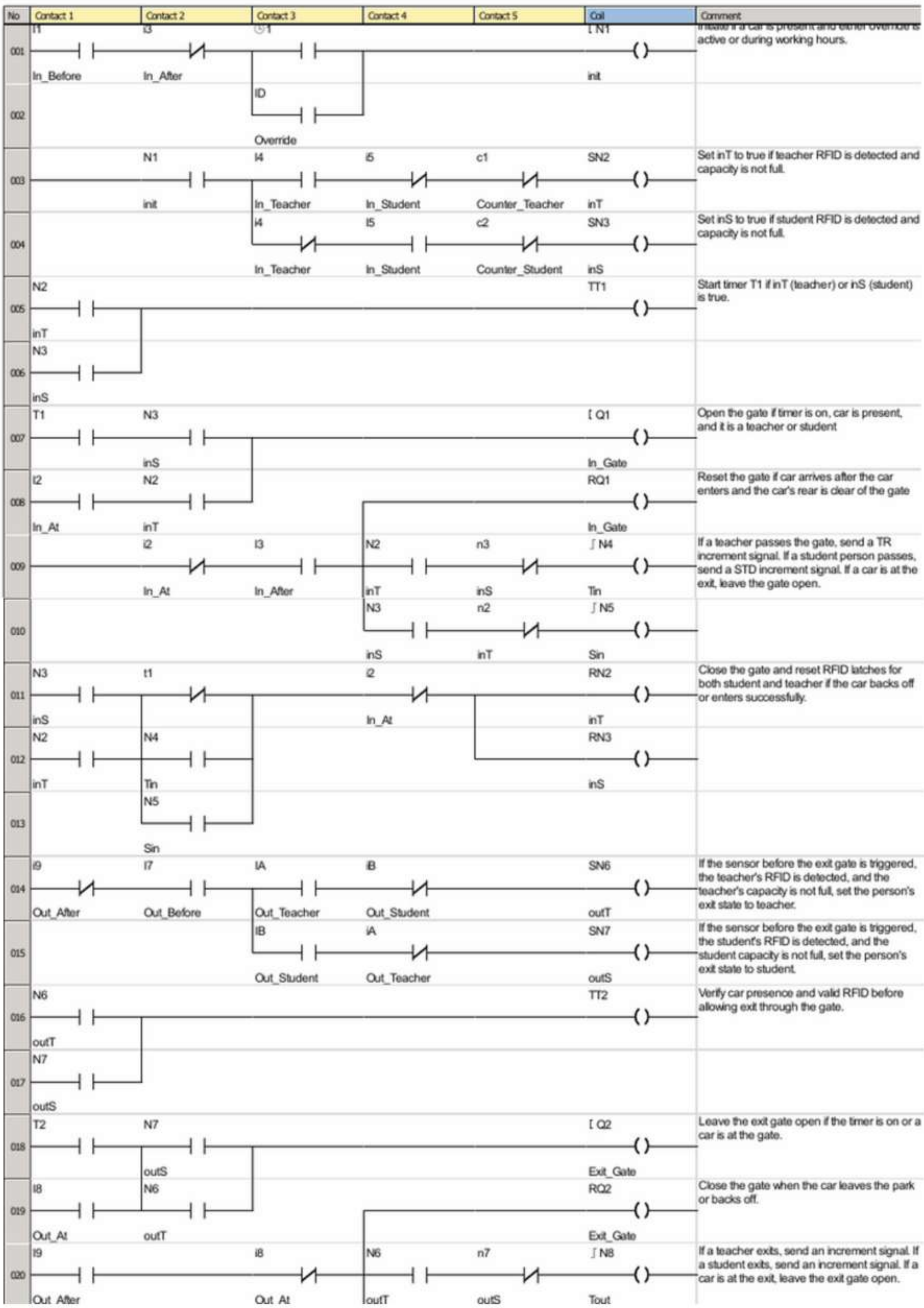
No	Function	Label	Type	Preset	Current	Lock	Comment
001	Timer	T1	B: On pulse one shot	T1 = 010.0 S	T1 = 000.0 S	No	
002	Timer	T2	B: On pulse one shot	T2 = 010.0 S	T2 = 000.0 S	No	
003	Counters	C1	Output ON when the	C1 = 00003	C1 = 00000	No	Counter_Teacher
004	Counters	C2	Output ON when the	C2 = 00004	C2 = 00000	No	Counter_Student
005	Clock	⏲1				No	
006	Text block	X1				Not Ap	DisplayScreen

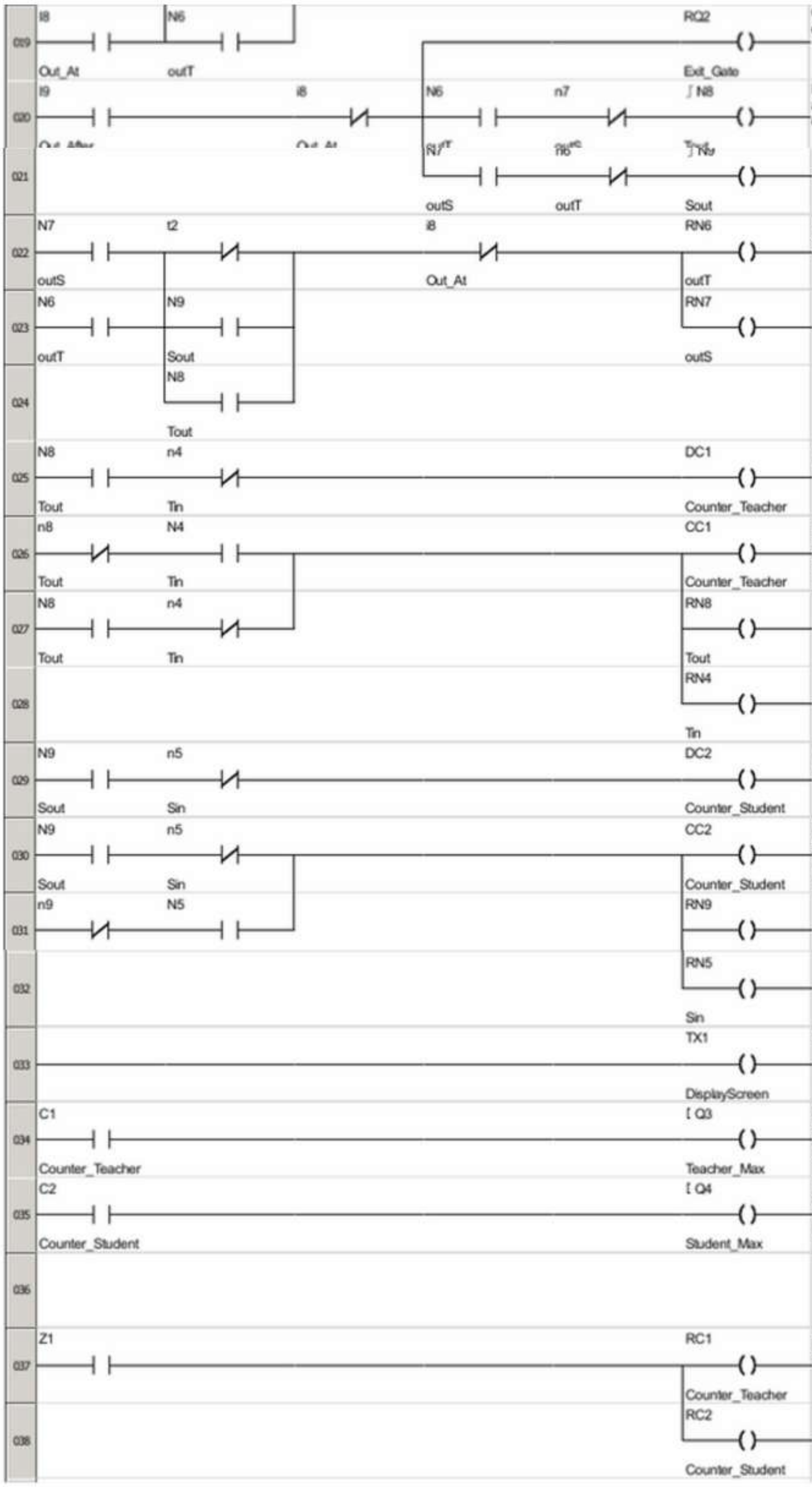


The System:

Below is the system design that fulfills the objective and focuses on all the possible scenarios.

Program diagram





Close the gate when the car leaves the park or backs off.

If a teacher exits, send an increment signal. If a student exits, send an increment signal. If a car is at the exit, leave the exit gate open.

If the car backs off, close the gate, reset student and teacher RFID latches, and do not increment.

If a teacher is exiting and no teacher is entering, decrement the teacher counter.

Increment the teacher count if a teacher is entering and not leaving, or if a teacher is leaving and not entering. Do not increment the teacher count if a teacher is both entering and leaving.

If a student is exiting and no student is entering, decrement the student counter.

Increment the student count if a student is entering and no student is leaving, or if a student is leaving and no student is entering. Do not increment the student count if a student is both entering and leaving.

Show available parking slots.

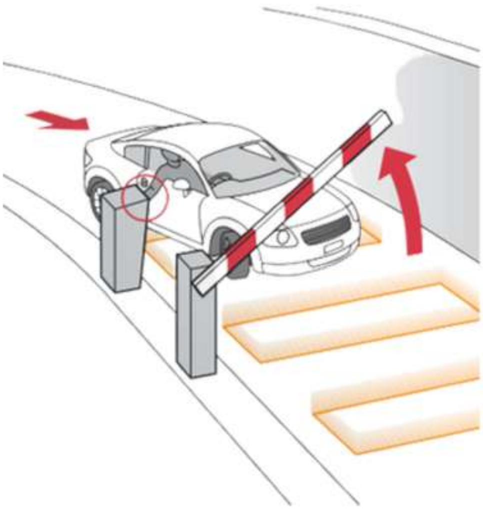
Display "Teachers: X/Y" (e.g. "Teachers: 5/10") where X is the current number of teachers and Y is the maximum available slots.

Display "Students: X/Y" (e.g. "Students: 20/30") where X is the current number of students and Y is the maximum available slots.

Reset at any time the number of teachers and students.

The Design:

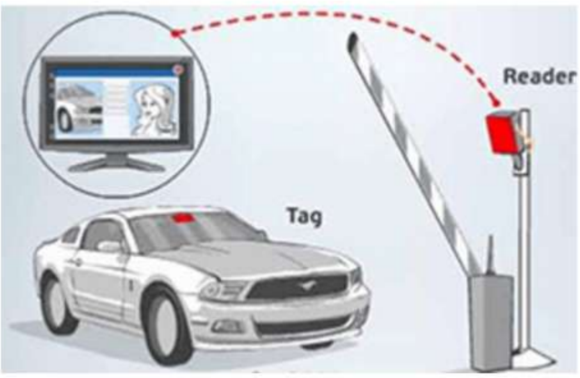
Feature	Inductive Loop	Infrared Sensors	Radar Sensors	Video Detection
Detection Method	Ground-based electromagnetic field	Passive/Active infrared light	Radio waves	Image analysis
Installation	Requires pavement cutting	Surface-mounted or overhead	Typically overhead or pole-mounted	Overhead or roadside mounted
Environmental Impact	Minimal after installation	May be affected by weather	Generally robust to weather	Can be affected by lighting
Accuracy	High detection accuracy	Moderate; can miss small vehicles	High accuracy	High accuracy with calibration
Cost	Moderate installation and maintenance cost	Lower initial cost, may require adjustments	Higher initial cost	Higher upfront and operational cost
Maintenance	Low, once installed	Moderate, may need recalibration	Moderate, can be complex	High, requires ongoing monitoring
Longevity	Long lifespan (10-20 years)	Shorter lifespan	Long lifespan	Varies, dependent on technology
Traffic Flow Monitoring	Excellent for traffic counts	Limited capability	Good for monitoring	Excellent for detailed analytics
Sensitivity to Vehicle Types	Highly sensitive to all vehicle types	May struggle with small vehicles	Sensitive to all types	Can be adjusted but may miss smaller vehicles



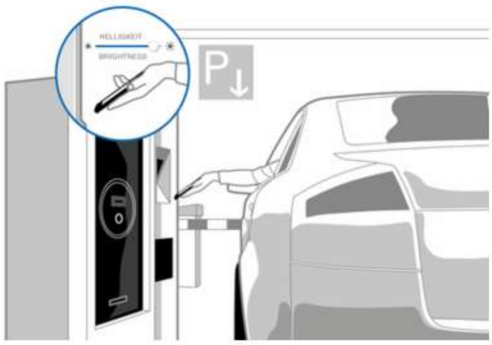
Inductive Loop Schematic

Infrared Sensor Schematic

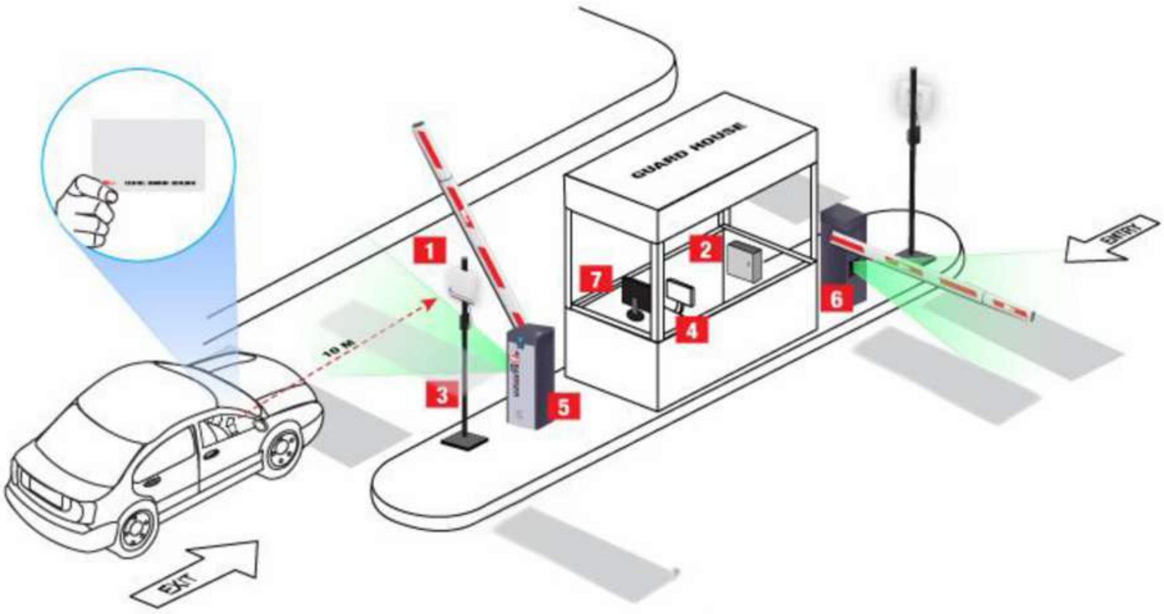
Feature	RFID	Barcode Scanning	NFC (Near Field Communication)	QR Codes
Detection Method	Radio waves to identify tags	Optical scanning of printed barcodes	Short-range radio communication	Optical scanning of printed QR codes
Range	Up to several meters (depending on type)	Typically within a few inches	Very short range (a few centimeters)	Typically within a few inches
Speed	Fast reading, can read multiple tags at once	Slower; one at a time	Fast, but limited to one tag at a time	Fast, but requires line of sight
Cost	Moderate to high (tags can be expensive)	Low for barcodes, moderate for scanners	Moderate for NFC tags and readers	Very low; generating QR codes is free
Installation	Requires a reader and setup	Requires scanners, minimal setup	Requires NFC readers, easy integration	Minimal setup; no special hardware needed
Durability	Tags can be durable and waterproof	Labels can wear out easily	Tags are generally durable	Paper-based codes can wear out
Data Capacity	High capacity (can store a lot of data)	Limited to the barcode format	Limited to NFC data standards	Limited to QR code capacity
Security	Can be encrypted, secure transmission	Vulnerable to copying	Secure; limited range reduces risks	Can be copied easily
Use Cases	Inventory management, access control	Retail checkout, inventory tracking	Mobile payments, access control	Marketing, product information



RFID Schematic


Barcode Schematic

<u>The Design:</u>



Gate Schematic

Key features include:

1. **Fast:** A single entrance and exit gate minimizes congestion and reduces the risk of traffic jams.

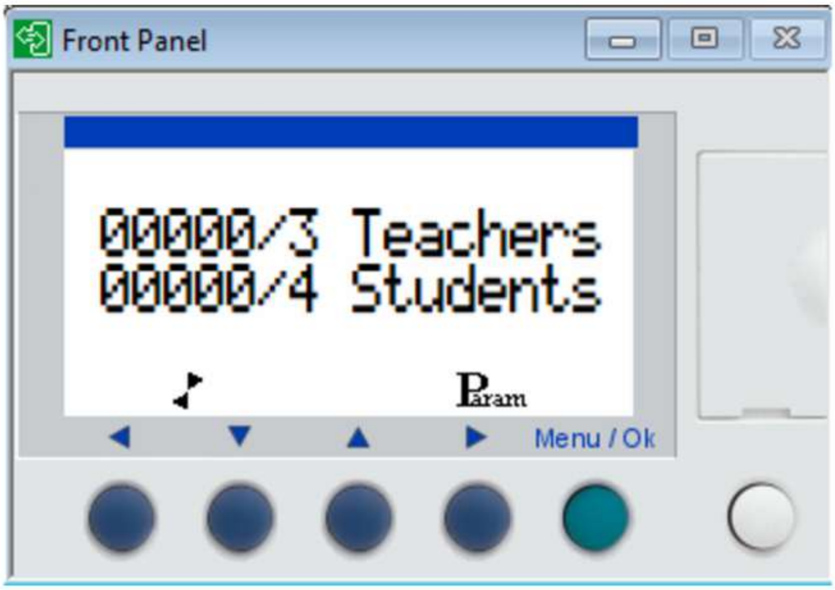
2. **Intelligent:** The system automatically updates parking availability and provides real-time information to users, ensuring a seamless and informed parking experience.

3. **Secure:** The system features RFID authentication and smart gate control to prevent unauthorized access, while also protecting users from potential gate-related accidents.

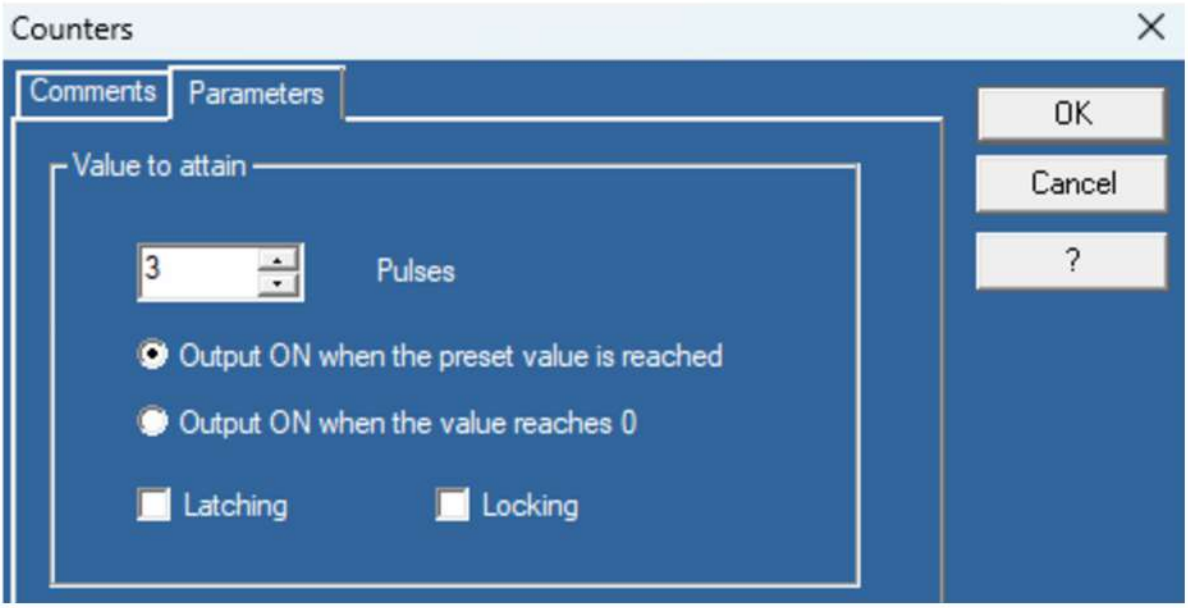
4. **Efficient and Reliable:** The design accommodates various scenarios, such as users backing off, simultaneous entry and exit, and paused vehicles under the gate.

Simulation Notes:

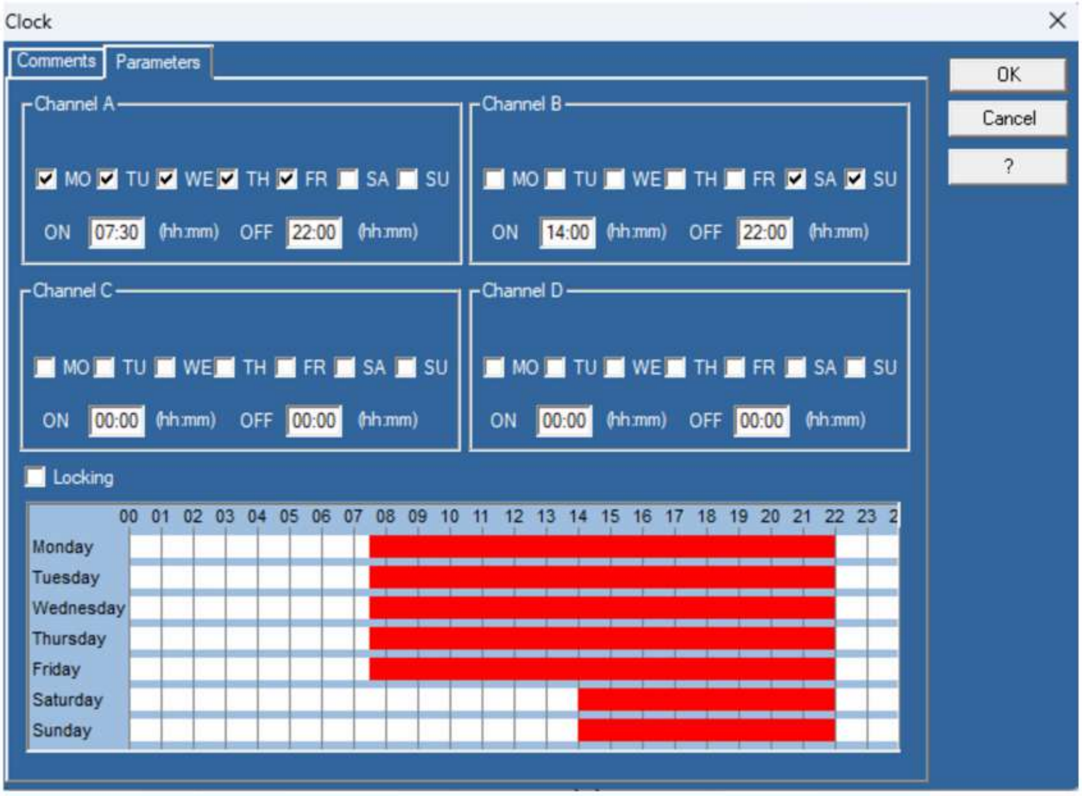
To access the Front Panel to view the Screen: Window > Front Panel



To update the number of slots in the parking for each category (Students or Teachers), Right Click on the respective counter > parameters window > change the value of the pulse to reflect the total of slots for this category.



To update the available hours for the parking, Right Click on the clock C1 > parameters window > update the respective hours to reflect the new ones.



Estimated Price Breakdown:

2 RFID Sensors ($15-$25 each), 6 Inductive Loop sensors ($120-$300 total), a PLC ($100-$300), and 2 LCD 16x2 displays ($5-$10 each), and installation fees ($400-$600), total roughly $940-$1,235.

Additional Suggestions:

- Implementing a redundant sensor in parallel with the existing Inductive Loop to ensure continuous functionality in the event of a single sensor failure.
- Implement a tracking system to synchronize the entry/exit gate counter with the parking space occupancy counter, ensuring a one-to-one correspondence between entries and allocated parking spots.

Conclusion:

The primary objective of this system is to facilitate a smooth and simultaneous entry and exit process for vehicles. To achieve this, two gates have been deemed ideal, allowing for efficient traffic flow in both directions. The combination of Inductive loops, and RFID technology ensures a reliable and user-friendly parking management system.