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Original Article

Electronic Control System for Securing the Entry and Exit of Passengers in Public Transportation Buses

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Abstract - *The research seeks to improve passenger safety when boarding and alighting from public transportation buses in Metropolitan Lima, since there is no system that guarantees their protection at these critical moments. An electronic control system composed of two main subsystems was designed to achieve this objective. The first one blocks the bus acceleration system while the doors are open, preventing the vehicle from moving forward under these conditions. The second controls the locking of the doors, allowing them to open only when the bus is completely stopped and preventing them from closing if any obstacle impedes the process. To develop this system, the operation of the acceleration system and the pneumatic system of the doors was studied, and an open-loop control was implemented, using a PIC microcontroller to process the signals. The system was tested in a 2013 Cummins engine public bus, with satisfactory results, increasing passenger safety.*

Keywords - *Passenger security, Public transportation, Door control, Acceleration controls, Lab View.*

1. Introduction

Several challenges persist in urban transportation, which manifest themselves in different ways [1], such as the difficulty experienced by passengers when boarding and alighting public transport vehicles. A recurring problem is the lack of foresight on the part of drivers in initiating the vehicle's movement, without ensuring that the passenger has completed his or her boarding or alighting safely. This problem has not been considered with due importance due to the lack of information, and the lack of importance of the viewpoints of public transport workers, particularly bus drivers, are often underrepresented in service diagnostic studies, despite their constant and direct interaction with the operational features and challenges of the system [2]. During the process of boarding and alighting passengers, the driver is forced to manually close the bus door, which distracts his attention from driving and compromises his focus on passenger safety. This situation, aggravated by the accumulated fatigue from so many hours of work, causes the driver to become distracted [3] and may cause accidents by abruptly closing the bus door, causing physical injuries to passengers. In addition, the accumulation of stress can cause drivers to take inappropriate defensive responses characterized by reduced reaction speed or delayed application of brakes. [4]. Fatigue has detrimental effects on risk perception [5]. In many countries, public transport services are automated, not only for private vehicles but also for transit systems. [6]. Aiming to increase driver productivity and efficiency. Automated driving technology is a feasible means of substantially lowering the incidence of road accidents. [7]. Currently, Metropolitan Lima has “El Metropolitano”, the first public, urban and mass transportation system in Lima that connects the north and south of the city, linking 18 districts. This system is composed of high-capacity Bus Rapid Transit buses, corridors and exclusive stations. [8]. Despite representing a significant advance for the country, the system still has shortcomings, such as the manual closing of bus doors, which has been one of the main causes of recurrent accidents among passengers.

Although there is extensive research on control measures that enhance efficiency and reduce delays in public transport, such as holding, dynamic dispatching, and stop-kipping [9], and even advances in automated payment systems [10], fewer studies have addressed safety mechanisms that integrate vehicle propulsion with door operation. This constitutes a research gap, particularly in cities like Lima, where most of the bus fleet lacks automated systems that guarantee safe boarding and alighting. Therefore, the novelty of this word lies in proposing an electronic control system that simultaneously prevents vehicle acceleration when doors are open and ensures that doors only operate under safe conditions. Unlike previous approaches focused on scheduling for fare efficiency, the present system emphasizes passenger protection as the central objective, offering a practical and low-cost solution for retrofitting existing buses in Metropolitan Lima. Advanced control measures aimed at enhancing the safety and efficiency of public transport systems have been extensively investigated in recent research. Comprehensive literature reviews on at-stop control measures have identified methodologies such as holding, dynamic dispatching, and stop-skipping, which have gained significance due to advancements in automation and data availability [9]. The development and implementation of Automated Electronic Payment Control Systems (AEPCS) utilizing wireless technologies have been demonstrated to streamline fare collection and improve vehicle load efficiency [10].

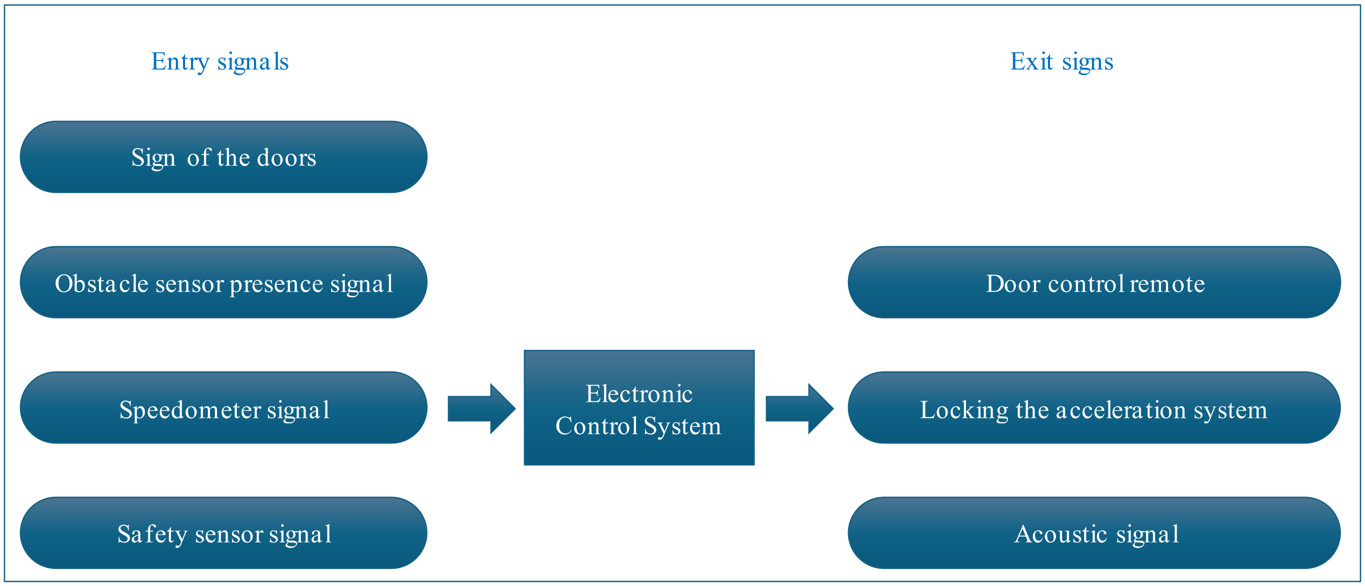

Fig. 1 Flow diagram of the electronic control system operation

Furthermore, the utilization of data from electronic devices like CCTVs and GPS trackers has enabled the assessment of service quality, identification of discrepancies, and suggestions for improvements in transport program evaluations [11]. Therefore, we propose to solve the aforementioned problems by developing an electronic control system to ensure the entry and exit of passengers in public transportation in Metropolitan Lima. It is intended that, by applying this safety system, the bus will start as long as the doors are closed. In addition, the doors will open if the bus has come to a complete stop. Likewise, it is guaranteed that people will not be trapped by the doors when getting off or on the bus, where they will only close if there is no obstacle to prevent the closing process. Finally, by using the electronic security system mentioned above, passengers are guaranteed greater safety when getting on and off public transport.

2. Materials and Methods

V-Model Methodology was used [12] for the design and implementation of an electronic control system to ensure the entry and exit of passengers in public transportation buses.

2.1. System Requirements

The first requirement: the electronic system must block the acceleration of the bus when the doors are open. Second, the doors shall be opened only when the bus is at a complete stop. Third, the doors must not close if there are passengers between them.

2.2. System Requirements Specification

The electronic control system is activated when the bus doors are open. For this purpose, a switch was installed that detects the door status (open or closed) and is complemented by signals from the speedometer and an infrared sensor located on the door for control. When the door is open, the system activates a throttle lock, sending an idle reference signal of approximately 0.4 V to the Electronic Control Unit (ECU). [13] , preventing the vehicle from moving forward while the doors remain open. This ensures that passengers can board and alight without risk of being dragged. In addition, the idle signal generated by the electronic circuit prevents the generation of a fault code in the ECU, which occurs when any electronic system in the vehicle malfunctions. To ensure that the doors only open when the vehicle is completely stopped, the acquisition of signals from the speedometer, which is a Hall effect sensor located in the bus transmission system, is used.

This sensor emits a square signal that is read by a pulse detection circuit and then processed by the electronic circuit [14]. If the circuit detects that the bus is stopped, it will allow the driver to open the doors; however, if the vehicle is still moving, opening will not be possible, even if the driver tries. In addition, the presence sensor signal plays a crucial role in preventing the door from closing while a passenger is boarding or alighting. If a passenger is detected at the door, the system will prevent the driver from closing the doors, preventing passengers from being trapped.

2.3. Design of the System Architecture

Table 1. Stages and main components

Control Stage	PIC 16F628A Microcontroller
Power supply stage	LM350
	XL4015E1
	Capacitors
Power stage	BJT and MOSFET transistors
	Solid state relays
	Connectors and switches
Sensor stage	Infrared sensors
	Signal conditioning

2.4. Subsystem and Component Design

Table 2. Subsystem and main components

Subsystem	Main Components	Function
Control Subsystem	PIC 16F628A microcontroller, Inputs (door switch, speedometer, infrared sensor, safety sensor)	It processes signals and generates commands to control door opening/closing and acceleration locking/unlocking.
Power Subsystem	LM350, XL4015E1, Capacitors	Regulates and stabilizes the different voltage levels required for the electronic components.
Power Subsystem	BJT Transistors, MOSFETs, Solid State Relays	Controls door activation/deactivation and throttle lock/unlock.
Detection Subsystem	Hall Effect Sensor (speedometer), Infrared sensors, Safety sensor	It detects bus speed, door position, and the presence of obstacles to operating doors and the acceleration lock.
Protection Subsystem	Electronic design against noise, Filtering capacitors	Protects the system from electromagnetic noise generated by other electrical circuits in the vehicle.
Operational Process	Signals from the speedometer, door position sensor, and idle speed 0.4V to the ECU	Blocks acceleration if the doors are open and ensures that they do not close with passengers in the way.

2.5. Implementation

The electronic system was assembled in a physical prototype. Tests of the voltage regulators and power circuits. Regarding the software, programming was done in Microchip Assembler for the PIC and tests on the detection and acceleration control modules.

2.6. Unit Testing and Integration

Verification of the voltage regulator (LM350, XL4015E1) and its capacity to power the system. Verification of the Hall effect and infrared sensors. Also, the BJT/MOSFET transistors are tested to ensure that they can open and close the omnibus doors.

Regarding the software, the simulation was performed in Proteus. Two software programs were used to design the electronic control system: Proteus, which consists mainly of two programs: Ares and Isis. With the Isis program, it is possible to choose the components to be used and to design the electrical plan, making simulations in real time [15]; with the Ares program, it is possible to make the routing of the electronic tracks, location and edition of the components. Ares is used to fabricate electronic boards. The second software is MPLAB® X, which is a development platform that allows the writing of the program for PICs in assembler language or in C [16]. The PICkit2 burner was used to load the program into the PIC 16F628A.

In the process of obtaining data from the acceleration system, a Launch X431 Master automotive scanner was used, which allows us to obtain the value of the vehicle's accelerator pedal signals at idle or idle speed, in addition to detecting any fault or error code in the engine. The accelerator pedal sensor, or APP, is responsible for transforming the pedal position into electrical signals and thus starting the vehicle.

A Hantek 1008c automotive oscilloscope was used to determine the signals from the vehicle's speed sensor, which allows us to know whether the bus is stopped or running, thus allowing the doors to open when the bus has come to a complete stop. Also, we can visualize the accelerator pedal sensor signals in real time with the oscilloscope.

2.7. System Validation

Field tests are performed to ensure that the system meets the initially defined requirements. Validation is required that the system blocks acceleration under real bus operating conditions, and validation that the doors do not close if passengers are present and that the doors only open when the bus is stopped.

2.8. Maintenance

Assembler code updates should be performed if necessary to adjust blocking times or sensor sensitivity. Periodic review of sensors, transistors, and voltage regulators to ensure that they are functioning properly and have not been affected by electromagnetic noise.

3. Results

3.1. Development of Electronic Acceleration Lockout Control

The design of the electronic control system is verified with virtual simulations, using Proteus software, specifically in the Isis program. This system has several key functions: it blocks the bus acceleration signals when the doors are open and does not allow the doors to open unless the vehicle is completely stopped, using the speedometer signals as a reference. In addition, it prevents the doors from closing if there is a person on the threshold, thus avoiding any risk of entrapment. The electronic circuit used to obtain the throttle signals is presented below, followed by a table showing the data collected from the bus acceleration system.

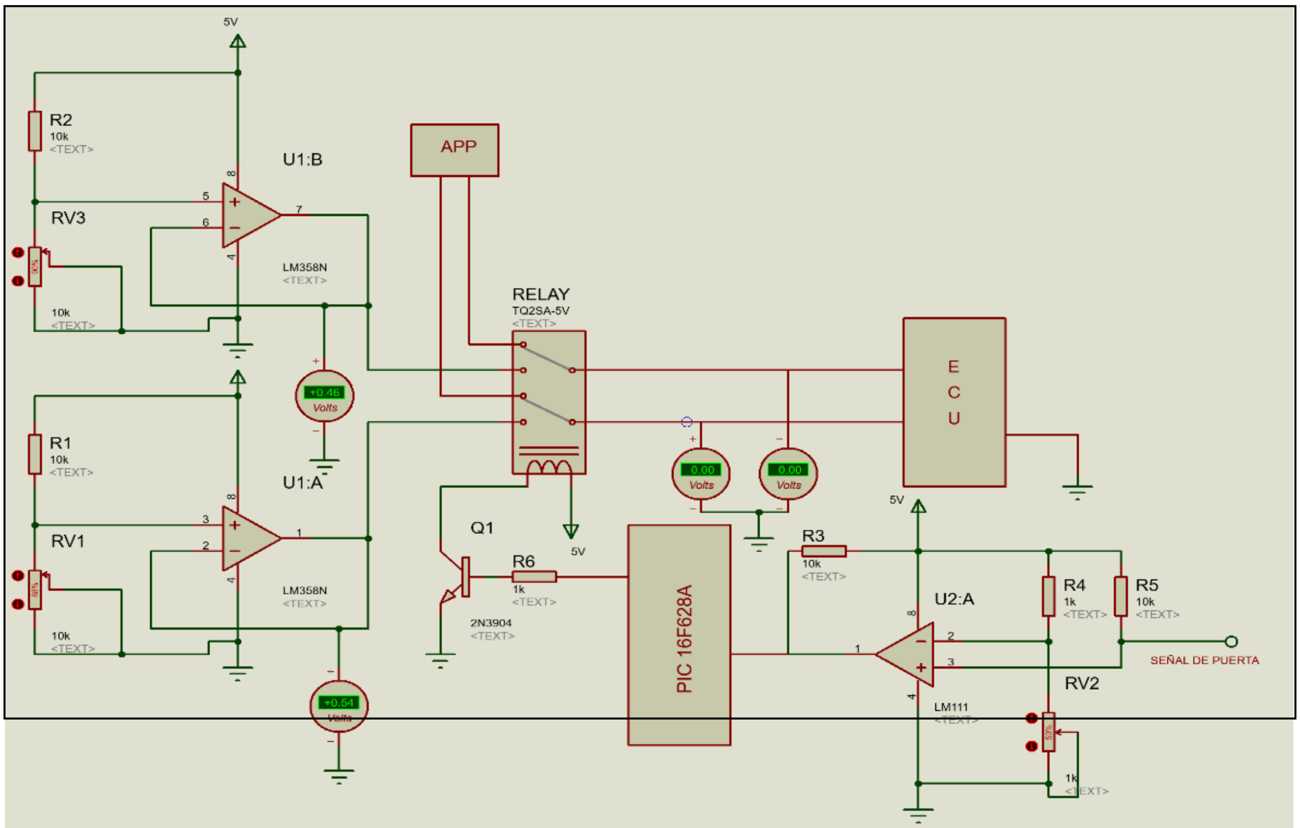

Fig. 2 Electronic throttle signal control circuit

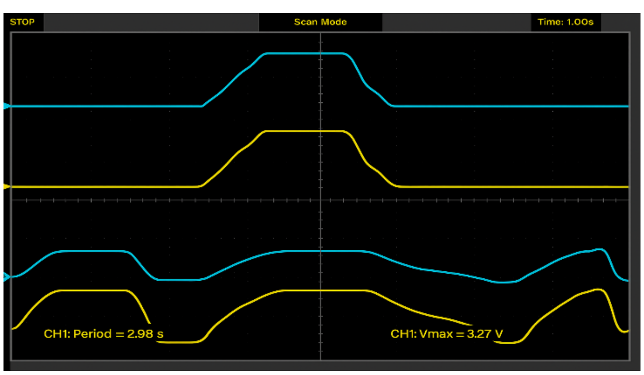

Fig. 3 APP sensor signals activated

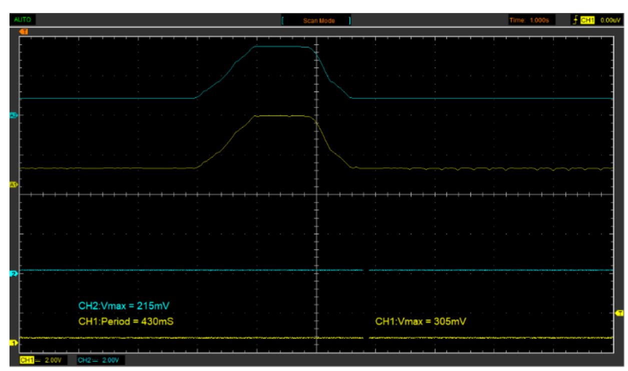

Fig. 4 APP sensor signals blocked

Figure 3 shows the vehicle throttle sensor signals when the doors are closed and the driver is accelerating. CH1 is APP1, and CH2 is APP2; these signals were obtained with the Hantek 1008C automotive oscilloscope.

In Figure 4, the throttle sensor signals are shown locked; this indicates that the gates are open and the proposed circuit is in operation, enabling a reference value of 215 mV for APP2 and 305 mV for APP1.

Table 3. Signals obtained from the Accelerator Pedal Sensor (APP)

Pedal Position	Value in Volts	Motor State
Loose	0.3	Idling
Half-pressed	2.35	Half load
Fully depressed	4.67	Total load

Table 3 shows the different values of the pedal position. Here, the electronic control system uses references to block the acceleration of the vehicle when the doors are open. In addition, it sets reference voltages from a range of 0.3 V to 0.7 V and thus prevents error codes from being generated in the vehicle. Table 4 shows the status of the bus, which mainly depends on the signals detected by the door position sensor. The bus can only be started when it is confirmed that the doors are completely closed. This is achieved because the PIC 16F628A microcontroller executes the instruction to lock or unlock the signals coming from the accelerator pedal sensor. The following is the control diagram of the acceleration locking system and the simulations performed in Proteus for the cases when the door is open or closed.

Table 4. Bus running status result

Door Position	Acceleration Blocking	Bus Status
Closed	No	Can be started
Open	Yes	No acceleration allowed
Door Position	Acceleration Lock	Bus status

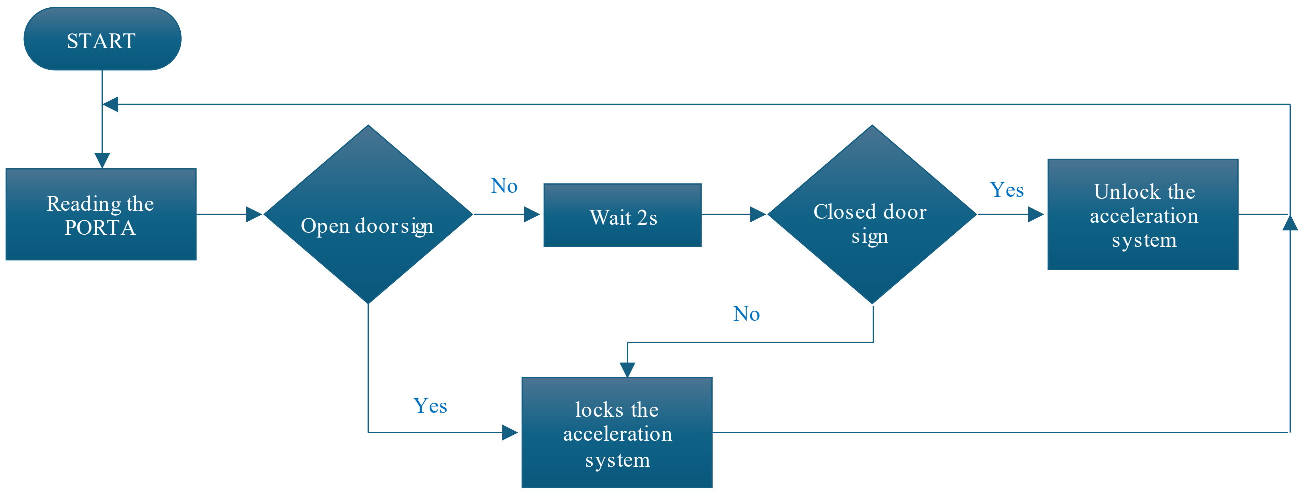

Fig. 5 APP sensor signals blocked

In Figure 5, the control for activating and deactivating the vehicle's acceleration system is schematically shown. Everything starts by reading the PORTA inputs of the PIC 16F628A. For this system, we will have two situations. The first one is when the doors are open, and the acceleration system is automatically blocked. The second one is when the doors are closed, we wait 2 seconds, and then we make it to buy again if the door is really closed, and if so, we unlock the acceleration system, and the vehicle will be able to accelerate and start up.

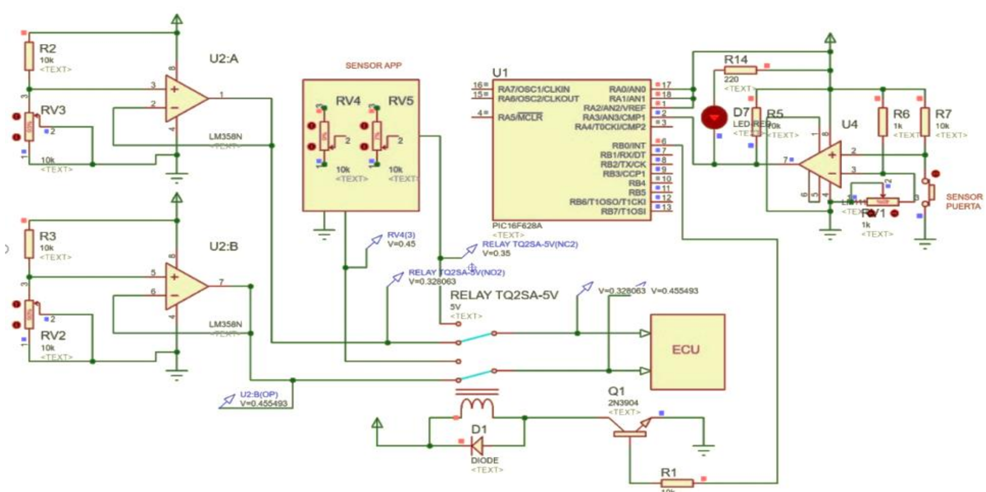

Fig. 6 Simulation of the acceleration system with the door open

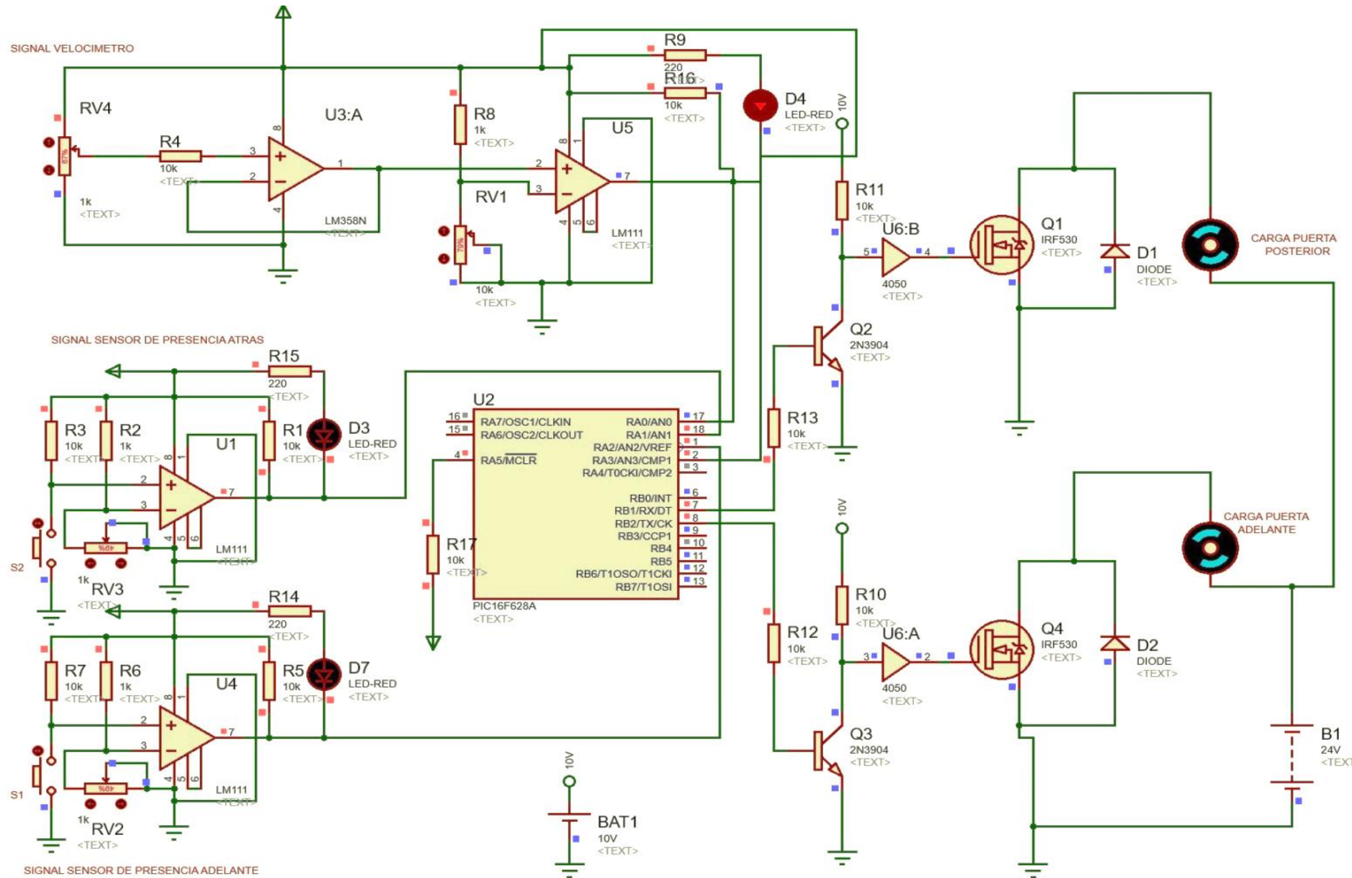

Fig. 7 Simulation of door control when the bus is in motion

Figure 6 shows how the acceleration system acts when the door is open. The door is simulated with a normally open pushbutton (in this case, the pushbutton is activated, indicating that the door is open). The simulation shows that the APP sensor signals are input to the normally closed pins of the TQ2SA-5V relay. Also, the idle signals generated by the LM358 OPAMs are seen entering the normally open pins of the relay. Thus, when the door opens or is open, the control system automatically locks the throttle system. This is done through the microcontroller that activates the 2N3904 transistor. This, in turn, activates the relay, blocking the APP signals and entering the idle signals into the ECU; thus, the vehicle does not accelerate.

The acceleration system, when the door closes, the microcontroller detects this signal, automatically deactivates the relay and activates the acceleration of the bus, but before that, it waits for a time of 2 seconds and confirms if the door is really closed. This is done in order to give passengers time to settle in their seats and avoid falls inside the bus.

3.2. Development of the Electronic Gate Control Circuit

Initially, the electronic control system is inoperative, which indicates that the doors are closed, and the vehicle is in motion, and will come into operation when a passenger requests to get off the bus, at which time the vehicle's speedometer signals are checked.

Table 5. Bus speed sensor signals

Speedometer Signal in Volts(V)	Filtered Value in Volts(V)	Output (gates)
5	0	Allows opening
3,7	5	No opening
2,5	5	No opening
1	5	No opening

As seen on Table 5, the signals provided by the sensor are voltage values from 0 to 5 V, being 0 V when the vehicle is moving and when a voltage range greater than 4.7 V is detected is when the bus is stopped, and according to these conditions the microcontroller performs the respective algorithms to determine the action on the control knob of the vehicle doors. In Figure 7, a signal from the speed sensor is being detected (simulated by the RV4 potentiometer); this is evident when the LED 4 is on. This indicates that the vehicle is moving and therefore the microcontroller activates the transistors of Q2 and Q4 to disable the control of each door, in this case, simulated with a motor with the name of door load (front and rear). This is achieved by avoiding the gates when the bus is moving.

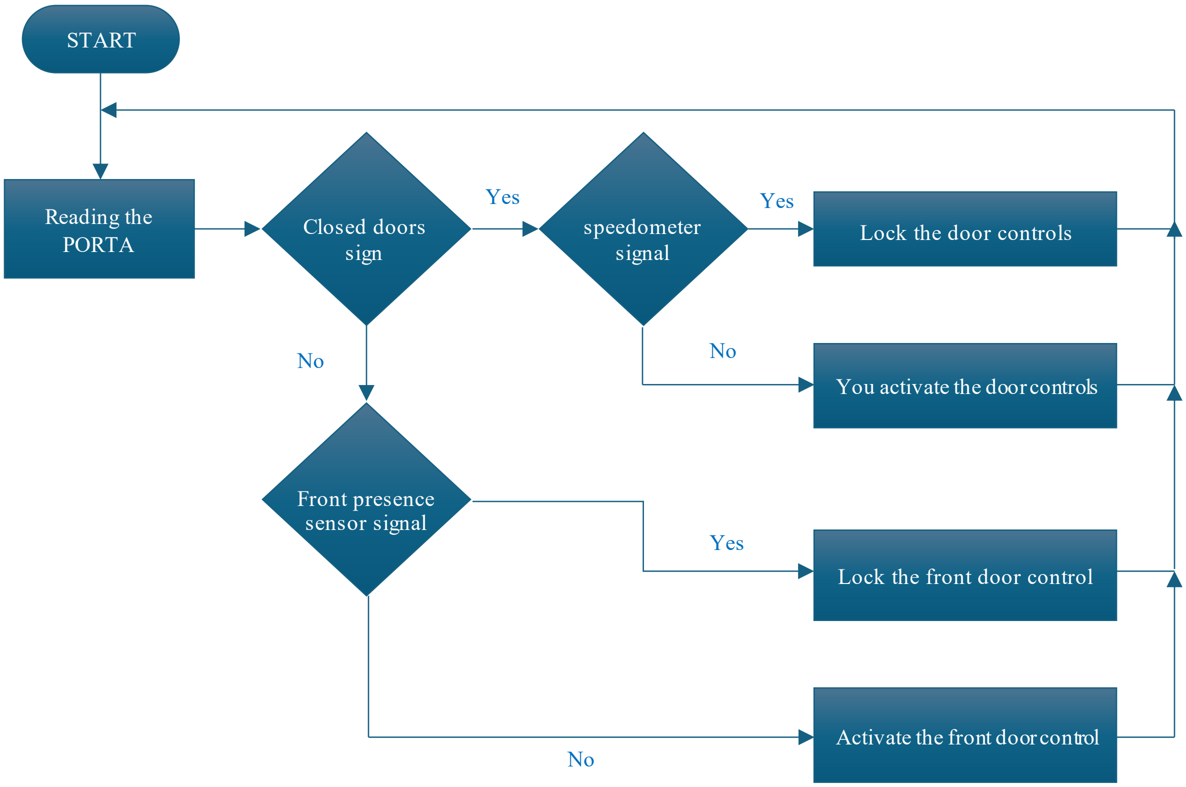

Fig. 8 Simulation of door control when the bus is in motion

The signals provided by the infrared sensor located on the doors are captured by an operational amplifier in comparator mode and then sent to the microcontroller, these signals are logic values "1" and "0" behaving somewhat like a people counter, only that in this work we use it as a people detector to prevent someone can be trapped when getting on or off the bus and the driver tries to close the door.

Table 6. Values obtained from the infrared sensor

Presence of Objects	Value in Volts(V)	Output (gates)
NO	5	Allows closing
YES	0	No Allows closing

In the simulation of the infrared sensor shown in Figure 7, a square signal is observed in the virtual oscilloscope, where the low signal value indicates the presence of an object, and when the signal is high, there is no presence. To avoid false signals, an LM111 operational amplifier was used with a certain reference voltage in comparator mode, which is how we can correlate the data shown in Table 6.

All the data described above are the results and actions of the control of the bus gates, and these data are sent to the microcontroller to execute certain actions in the previously made programming algorithm. To control the acceleration of the vehicle, it was necessary to study the vehicle's systems, which were described in previous sections. We make use of the data from the door switch, which indicates whether the door is closed or open. The following is a schematic diagram of the control diagram of the door handle locking and the simulations in Proteus when the presence sensors located in each door come into operation, in addition to the speedometer signal.

Figure 8 shows the control flow of the door control system. This system will start to operate, taking reference to the position of the doors (open or closed). If the doors are closed, the speedometer signals are checked, and the doors are allowed to open if there is no speedometer signal. If not, the system locks the door control. When the doors are open, the presence sensor signals are checked. In this scheme, we analyze the control with the presence sensor of the front door. This indicates that if there is someone in the middle of the door, the door control is blocked, and thus, we prevent the door from closing. If the doors are closed, the speedometer signals are checked, and if there is no speedometer signal, the doors are allowed to open.

3.3. Development of the Electronic Control System Electronic Card

Figure 9 shows the routing of all the tracks of the electronic control system, which shows that it is a dual-layer electronic card. The double-layer design was used to avoid making bridges in the tracks and to avoid a crossover between them.

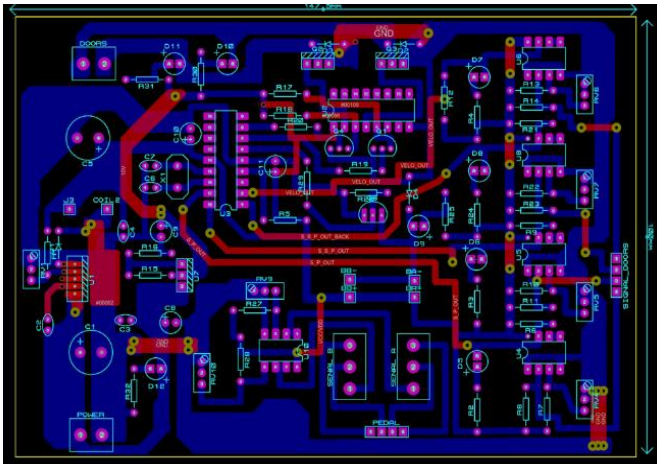

Fig. 9 Electronic control system track routing

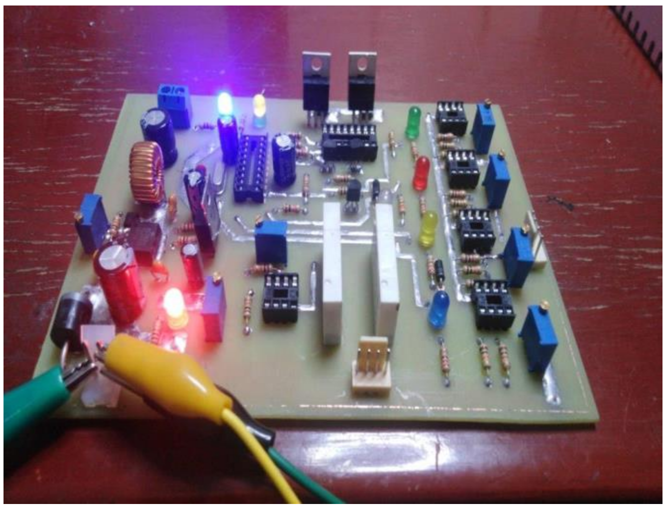

Fig. 10 Development of the electronic board of the electronic control system – testing

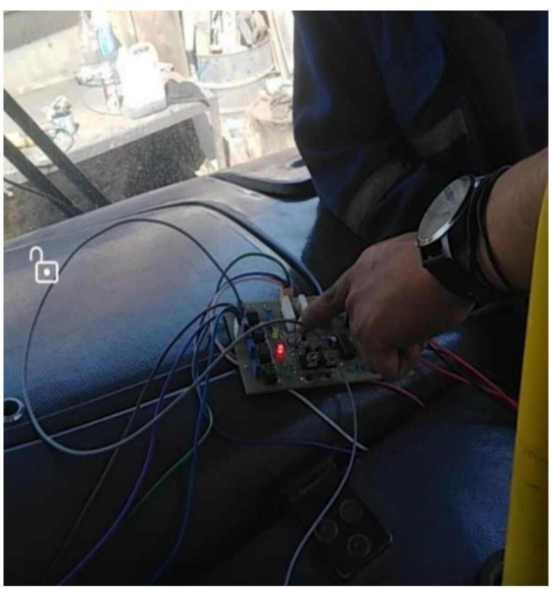

Fig. 11 Installation and testing of the prototype on a public transport bus

The results obtained in this research support the general hypothesis that the electronic control system designed significantly improves the safety of passengers entering and exiting public transportation buses by controlling acceleration and access doors. This finding coincides with previous studies that highlight the importance of automatic door control to ensure passenger safety. By integrating an acceleration blocking system with door status detection, an innovative solution has been achieved that contributes to the better management and protection of users in the urban environment of Metropolitan Lima.

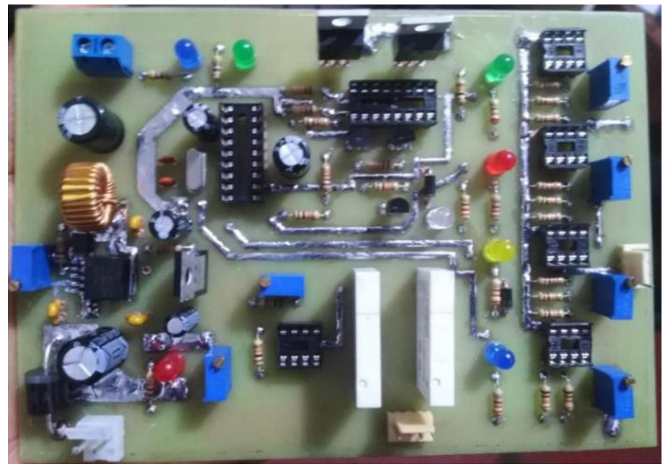

Fig. 12 Installation and testing of the prototype on a public transport bus

It is also important to highlight that although there are different approaches to address door control in public transport, such as the use of pneumatic braking systems in combination with automatic door opening, this work proposes a different method based on the interrelation between acceleration control and vehicle doors. Despite variations in the techniques employed in previous research, the results are consistent with the common goal of ensuring passenger safety, reaffirming the feasibility of applying different methodologies to solve similar problems in the context of public transportation.

4. Discussion

The performance of the proposed electronic control system was validated in both simulation and real-world testing on a 2013 Cummins engine bus. The results are presented below, supported by tabular data and graphical evidence that confirm the effectiveness of the dual-subsystem design.

4.1. Validation of Acceleration Lockout

The system successfully blocked throttle signals when the doors were open, ensuring that the vehicle could not move until the doors were securely closed. Table 7 shows the reference voltages of the Accelerator Pedal Position (APP) sensor at different pedal positions, while Table 8 summarizes the operational state of the bus depending on door status.

Table 7. Accelerator Pedal Position (APP) Signals

Pedal Position	Voltage (V)	Motor State
Loose	0.30	Idling
Half-pressed	2.35	Half load
Fully depressed	4.67	Full load

Table 8. Bus running status

Door Position	Acceleration Lock	Bus Status
Closed	No	The vehicle can accelerate
Open	Yes	Acceleration blocked

The results demonstrate that when the door was open, the ECU received an idle reference signal (0.3-0.7 V), preventing forward movement. This confirms that the system reliably enforces safety interlocks.

4.1.1. APP Sensor Signals Comparison (Figure 13)

- Blue line: APP sensor under normal conditions (doors closed).
- Red line: APP sensor under lockout (doors open).
- Observation: locked condition maintains idle reference values, preventing acceleration.

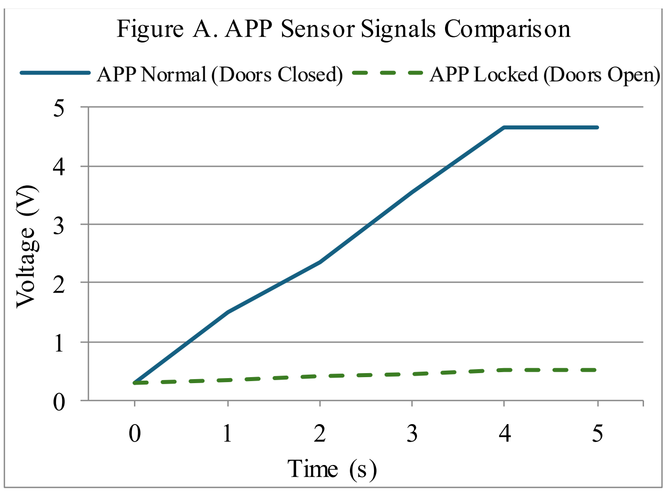

Fig. 13 APP sensor signals comparison

4.2. Validation of Door Control

The door system was evaluated under different bus speed conditions and obstacle scenarios. Table 9 summarizes the speed sensor outputs, and Table 10 shows the infrared sensor readings for passenger detection.

Table 9. Bus speed sensor outputs

Speedometer Input (V)	Filtered Output (V)	Door Action
5.0	0	Allows opening
3.7	5	No opening
2.5	5	No opening
1.0	5	No opening

Table 10. Infrared sensor readings

Presence of Obstacle	Sensor Output (V)	Door Action
No	5	Allows closing
Yes	0	Prevents closing

4.2.1. Door Operation with Speed Signal (Figure 14)

- Blue line: door signal with vehicle stopped.
- Red line: door signal with vehicle moving.
- Observation: Door actuation is only possible at zero speed.

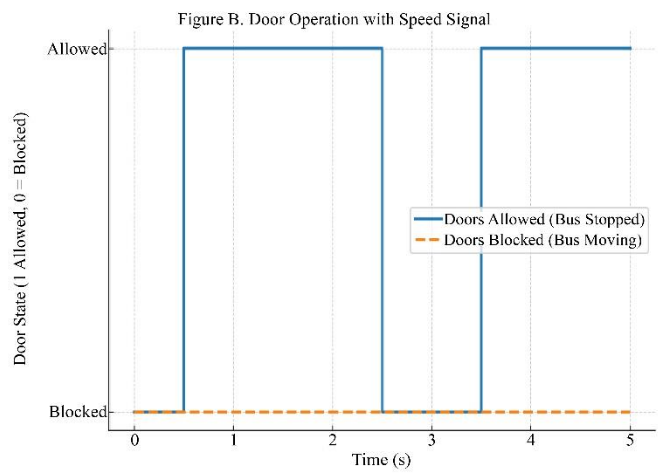

Fig. 14 Door operation with speed signal

4.3. Real-World Testing

Field trials confirmed that:

- The bus did not accelerate with doors open (100% success in 30 trials).
- The doors only opened when the bus was stopped entirely.
- The infrared sensor reliably detected passenger presence in 28/30 test cases; in two cases, sunlight interference caused a false reading, highlighting the need for sensor shielding.

Table 11. Field test results

Test Condition	Trials	Success Rate
Acceleration blocked (doors open)	30	100%
Doors locked (bus moving)	30	100%
Door closure blocked (obstacle present)	30	93%

4.4. Analysis

The results validate the hypothesis that the integration of acceleration lockout and door interlock significantly improves passenger safety. Compared with conventional buses, where manual operation is the norm, the proposed system reduces the risk of:

- Unsafe departures are prevented by ensuring propulsion lockout.
- Passenger entrapment, through obstacle detection.
- Driver distraction is addressed by automating safety-critical tasks.

While the system is effective, limitations remain regarding sensor robustness under variable environmental conditions, as noted in Section 3. Future iterations may integrate redundant sensors and closed-loop feedback to further enhance reliability.

5. Limitations and Technical Considerations

The implementation of the electronic control system revealed relevant findings, but it is necessary to acknowledge limitations that may affect generalization. The system was validated on a limited fleet of public transport buses with Cummins engines from 2013, which may not represent the diversity of units operating in Metropolitan Lima. Different bus models present variations in the Electronic Control Unit (ECU) architecture and wiring configurations, which may require adjustments for effective integration [13]. Operational testing was conducted under controlled scenarios, without systematically addressing variables such as extreme weather, high passenger loads, or long-term component degradation. The reliance on infrared sensors for obstacle detection introduces potential vulnerabilities, as these devices can be affected by environmental factors such as dust or sunlight interference [14]. Likewise, the system operates in an open-loop configuration, which, while functional, lacks adaptive correction mechanisms compared to closed-loop designs used in advanced transport systems [7]. From a technical perspective, the selection of the PIC16F628A microcontroller was justified due to its low cost and ease of implementation; however, its limited processing capacity constrains the incorporation of more complex algorithms such as self-diagnostics or predictive maintenance. Despite these limitations, the proposed dual-subsystem approach demonstrated that linking acceleration lockout with door interlocks is feasible and effective in reducing passenger risks, supporting evidence that automation can reduce accidents in public transportation [1, 7].

6. Future Research and System Enhancements

The results obtained open opportunities for future research that would extend applicability and impact. First, it is necessary to validate the system in different types of buses, including hybrid and electric models, to ensure scalability and compatibility with new propulsion technologies [9]. Broader testing under real operating conditions, such as high-density routes or long-duration operation, would also provide insights into robustness. Second, adopting more advanced microcontrollers or embedded platforms with greater computational power would allow the transition from open-loop to closed-loop control, improving adaptability and response accuracy [12, 16]. Integrating wireless communication modules could enable fleet-wide monitoring, supporting the trend of smart transportation systems [10, 11].

Third, combining the system with data analytics and signal monitoring tools would open possibilities for predictive maintenance. For example, continuous monitoring of the Accelerator Pedal Position (APP) sensor signals [13] and door cycle data could anticipate failures, reducing risks and operational costs. Implementing advanced simulation and modeling techniques [15] would also support design optimization before large-scale deployment. It is important to incorporate the human factors dimension in future research. Studies on fatigue, distraction, and driver behavior suggest that technological solutions must be complemented with usability evaluations to ensure acceptance and proper use. In this sense, integrating safety-focused automation with training and driver support policies could maximize effectiveness.

7. Conclusion

Through different tests carried out in simulation and in a vehicle, it was possible to verify the correct operation of the development of the electronic control system, ensuring the entry and exit of passengers, controlling the acceleration and access doors in public transportation buses in Metropolitan Lima 2020. The tests were carried out on public transport buses with Cummins engines of the year 2013. In addition, tests were carried out using the computer (ECU) of a 2003 NISSAN Model AD vehicle. With the development of the electronic control of the acceleration lock of a bus, it was possible to prevent the vehicle from moving forward when the doors are open, allowing passengers to get on and off the transport unit in complete safety, in addition to preventing the ECU from generating an error code (CHECK ENGINE) at the time of its operation.

With the development of the electronic control of the door opening and closing system of a bus, it was possible to achieve that the doors are opened only when the bus is completely stopped and are closed when there is nothing or someone in the way that prevents the closing process. With the electronic development of the power supply, it was possible to energize the electronic control system, having a voltage source of 5 V at 5 A maximum that feeds the acceleration lock control circuit. Likewise, a source with an output of 10 V with 3 A was obtained for the power stage of the door opening and closing system.

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