Design, Simulation, and Implementation of a Low-Cost Digital System for Crowd Management

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Abstract

This paper presents a low-cost, modular, LDR sensor-based crowd management system. The system utilizes dedicated entry and exits detection modules, each incorporating an LDR–laser setup and LM358 comparator circuits to generate digital count pulses. These pulses are processed by independent controllers driving seven-segment displays for real-time entry and exit counts. A central controller calculates net occupancy, compares it against a user-defined threshold, and triggers the entrance gate to close, currently implemented as an LED indicator when the limit is exceeded. The system was simulated in Proteus with varying crowd flow rates to evaluate accuracy. The results show that the system can count to three people per second. The entrance gate responds within 445 µs, corresponding to the total measured propagation delay from input trigger to gate activation while consuming only 1.8 W of power. These findings demonstrate the system's reliability, fast performance, and adaptability for integration with automated gates. Unlike existing high-cost solutions, this design uses simple, low-power components and a dual-controller architecture to maintain accurate counts with minimal processing overhead. The proposed solution is particularly suited for event venues, transport hubs, and other controlled-access environments where real-time crowd regulation is essential.

Keywords

Smart crowd management, Low-cost design, Comparator circuit, LDR, Digital system

Introduction

Overcrowding in public spaces poses significant safety risks and can cause operational inefficiencies during events or peak hours, as it not only compromises passenger comfort and service efficiency in transport systems (Tirachini et al., 2013) but also heightens perceived risk and reduces safety in large-space buildings (Alkhadim et al., 2018). With the rapid increase in urbanization and mass gatherings, effective crowd management has become a critical component

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of modern infrastructure. Conventional methods such as manual fall servision and closed-circuit television (CCTV) monitoring often fall short in delivering real-time intuitions and automatic decision-making competencies (Bhuyan, 2007). Consequently, the integration of intelligent sensing technologies and automated control systems has emerged as a promising solution for ensuring both safety and efficiency in crowded environments.

Recent research demonstrates the growing relevance of sensor-based solutions in various application domains. For example, Chen et al. (2023) proposed a LiDAR-based outdoor crowd management system that leverages edge computing to estimate pedestrian density in smart campuses while maintaining privacy. Similarly, Bong et al. (2008) introduced the Car Park Occupancy Information System (COINS), where sensor-driven approaches efficiently monitor vehicle flow and provide real-time availability information to users. These works highlight the effectiveness of real-time sensing and automated feedback systems in dynamic environments.

Building upon these concepts, the present project aims to develop an automated crowd flow management system that integrates people-counting sensors, gate control mechanisms, and digital displays to regulate entry/exit flow in real time. Unlike traditional monitoring techniques, this design emphasizes immediate responsiveness by automatically triggering gate operations when thresholds are exceeded. Such an approach ensures both operational efficiency and safety, making it suitable for deployment in transport hubs, campuses, and large-scale events.

Literature Review

LiDAR-based systems have also come to the forefront. Chen et al. proposed an outdoor crowd management framework using edge-deployed LiDAR for privacy-preserving, high-accuracy detection. Their approach includes both clustering and CNN-based processing of point-cloud data, achieving up to 95.8% accuracy in recognizing pedestrian counts—highlighting LiDAR's value in smart campus and smart city contexts (Chen et al., 2023).

Within buildings, combining in-situ sensors with crowd-sensed data improves understanding of occupant presence patterns and their operational impacts. A case study shows how fused sensing can relate presence to comfort and energy use, underscoring the value of accurate, time-resolved occupancy for operational decisions and compliance (Rusek et al., 2022).

At the city scale, mobile crowd sensing (MCS) aggregates smartphone signals to infer traffic and crowded conditions. A survey synthesizes MCS-based traffic efficiency models, highlighting their ability to produce scalable flow and density estimates for management tasks while calling out challenges around privacy, sampling bias, and energy constraints (Ali et al., 2021). These findings suggest MCS is powerful for area-level trends, but it may be overkill and costlier for door-level access counting.

Besides, smart staircase design shows an interactive infrastructural intervention for social distancing, using embedded sensors and real-time feedback to guide pedestrian movement. By visually signaling when staircases reach certain occupancy levels, the design offers a proactive yet low-cost method for managing crowds in constrained spaces (Assem et al., 2021).

In public transport environments, Virgona et al. (2015) focus on real-time sensing of travelers passing through congested stations. Although details are limited, their work suggests that technology-like perception, including cameras, pressure sensors, or proximity devices, can detect flow dynamics and help control crowd density in transit systems (Virgona et al., 2015).

Real-time occupancy awareness is a prerequisite for safe capacity control in public spaces. AFOROS presents a low-cost, passive Wi-Fi sensing platform that estimates attendance by fingerprinting 802.11 probe requests and reports ≈95% accuracy across real events, explicitly motivating occupancy control for safety and operations (Tirachini et al., 2013). AFOROS also contrasts technologies, noting that simple beam-break counters and camera systems are common but can be infrastructure- or processing-intensive depending on scale (Vega-Barbas et al., 2021).

For low-cost deployments using existing infrastructure, image-based occupancy has also been explored. The COINS system reuses CCTV feeds and applies image processing to deliver live car-park occupancy information, avoiding per-spot sensors but requiring compute and camera placement/calibration (Bong et al., 2008). This illustrates a classic trade-off between hardware simplicity at the edge and processing complexity centrally relevant when choosing between camera, Wi-Fi, or beam-break sensing for crowd control at entrances.

Methodology

The proposed crowd management system is designed to detect, count, and regulate the number of individuals entering and departing a monitored area. The implementation was carried out in a Proteus simulation environment before hardware prototyping. The scheme comprises four key sub-schemes, as shown in Figure 1. The subsystems include the entry counting module, the exit counting module, the operational module, and the event control module. The entry counting module detects and increments the crowd count as well as displays the counts when a person enters that area. The exit counting module detects and decrements the count when a person leaves and displays the count. The operational module calculates net occupancy and compares it with a predefined threshold. The event control module gets signals from the operational module and triggers the main entrance gate whenever the environment is crowded, and resets when needed. The triggering systems can be switched between different crowd management thresholds.

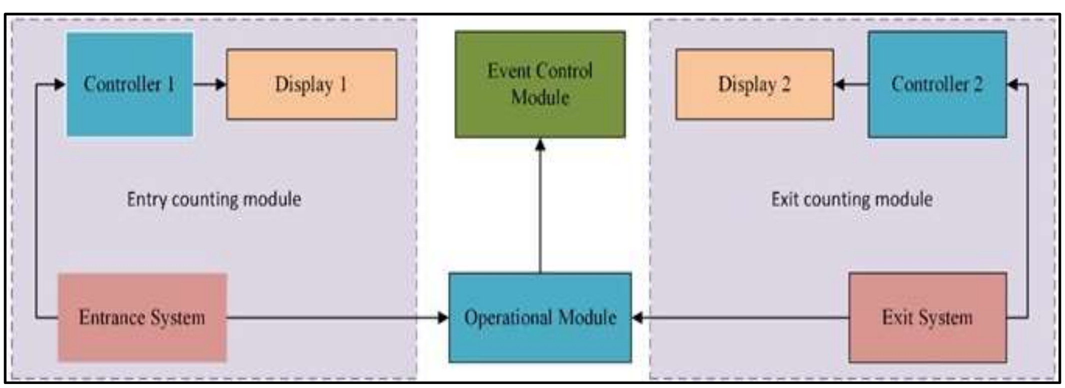


Figure 1. Block diagram of the overall scheme

The entrance system incorporates an operational amplifier (LM358) along with three resistive components, such as RV1, RV2, and RV3, where RV2 is a fixed resistor, RV1 functions as a light-dependent resistor (NSL-19M51), and RV3 is a variable resistor used for tuning the system under varying ambient light conditions, as shown in Figure 2. A NOT gate (74LS04) is employed to invert the clock output. An external clock source is included solely for testing purposes. The exit system circuit is the same as the entrance system circuit.

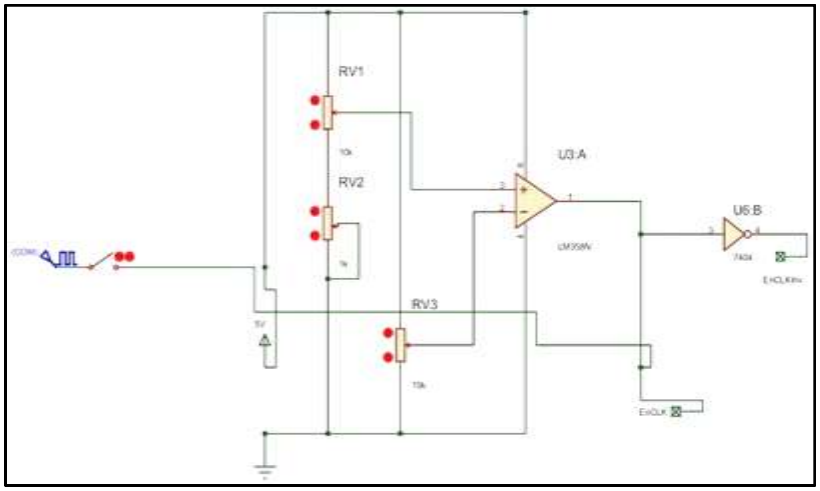


Figure 2. Electronic circuit diagram of the entrance system

Controller 1, as in Figure 3, integrates three 7-segment display-driver ICs (CD4026BE), which perform both counting and decoding operations. Controller 2 is the same as controller 1. The system allows switching between different crowd control thresholds via manual switches.

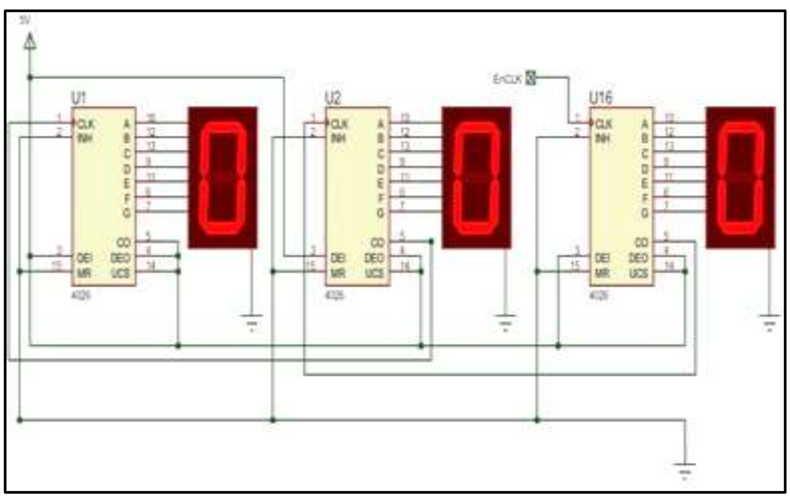


Figure 3. Electronic controller circuit diagram with 7-segment displays

A 12-stage ripple-carry binary counter (CD4040B) is used to count pulses from the clock input, as shown in Figure 4. Its output is fed into a 4-bit binary full adder (74LS283D), which is cascaded to form an 8-bit circuit. The resulting output is then fed to a 4-bit decoder (74LS154), which serves as a triggering circuit to activate or reset the system based on operational requirements.

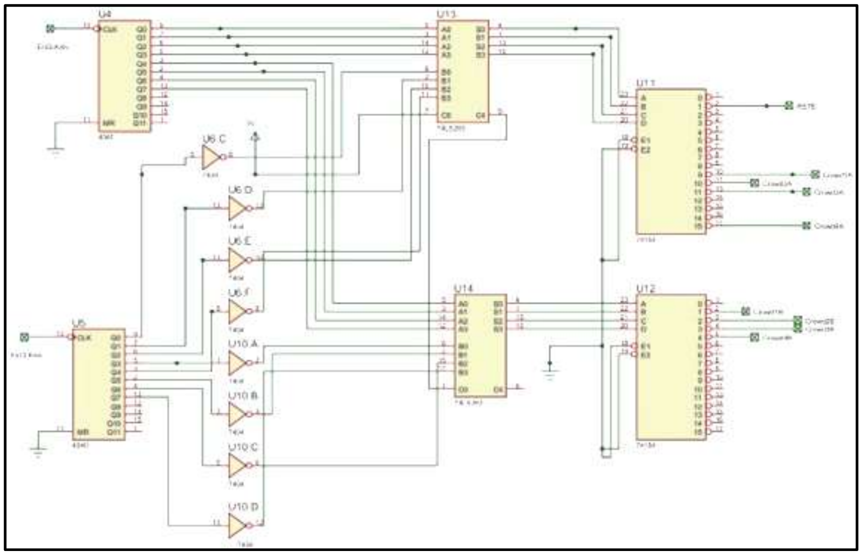


Figure 4. Electronic controller circuit diagram for the operational control

A NOR gate (74LS02) is used to generate trigger signals based on selected decoder outputs. Discrete components, like a diode, an LED, a BJT, a MOSFET, a capacitor, and a NOT gate (74LS04), are combined to drive external loads, for controlling the entrance gate, as in Figure 5.

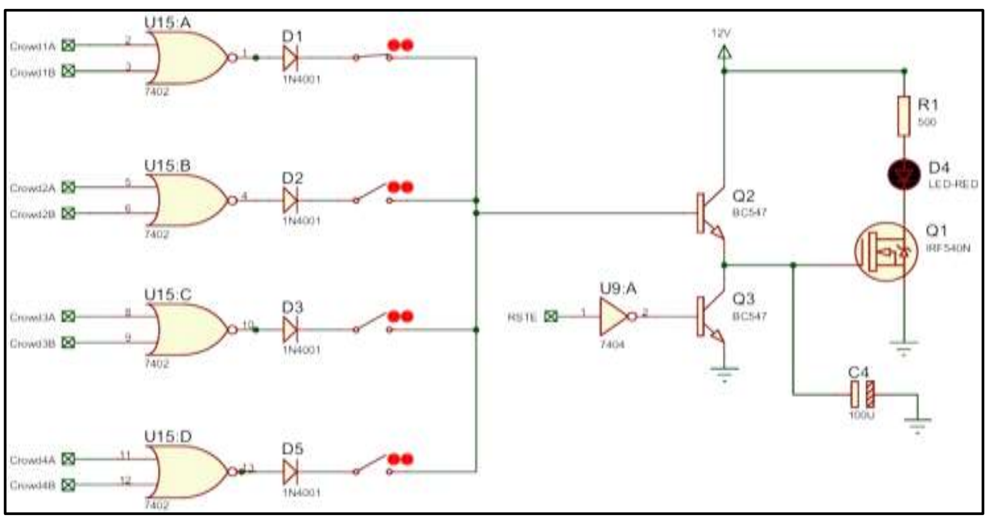


Figure 5. Electronic controller circuit diagram for the event count control

Results and Discussion

The proposed system was tested both under practical operating conditions and in simulation to evaluate its performance parameters. For testing, the system frequency was set to 3 Hz, allowing it to count and operate up to three persons per second. The supply voltage was 9 V, while all logic levels of the ICs were operated at 5 V through a voltage regulator IC (7805). Certain modules, like

LASER sensors and comparators, were powered directly from the 9 V, as shown in Figure 6. The system drew an average current of 200 mA, consuming power of approximately 1.8 W.

Figure 6. Hardware setup of the analog and digital electronic circuit for real-time testing

The measured waveform in Figure 7 confirms a total propagation delay of nearly 445 µs from the input trigger to the gate response. The measured fall delay of the output signal, shown in Figure 8 (a), is approximately 684 µs. Minimal ripples during switching indicate a reliable system performance. The measured rise delay of the output signal is around 635 µs, as in Figure 8 (b), indicating that the output will trigger almost instantaneously.

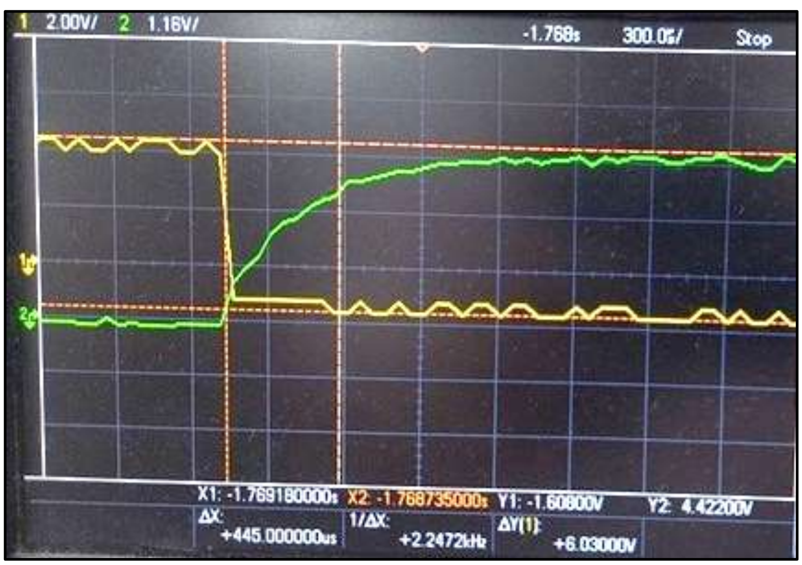
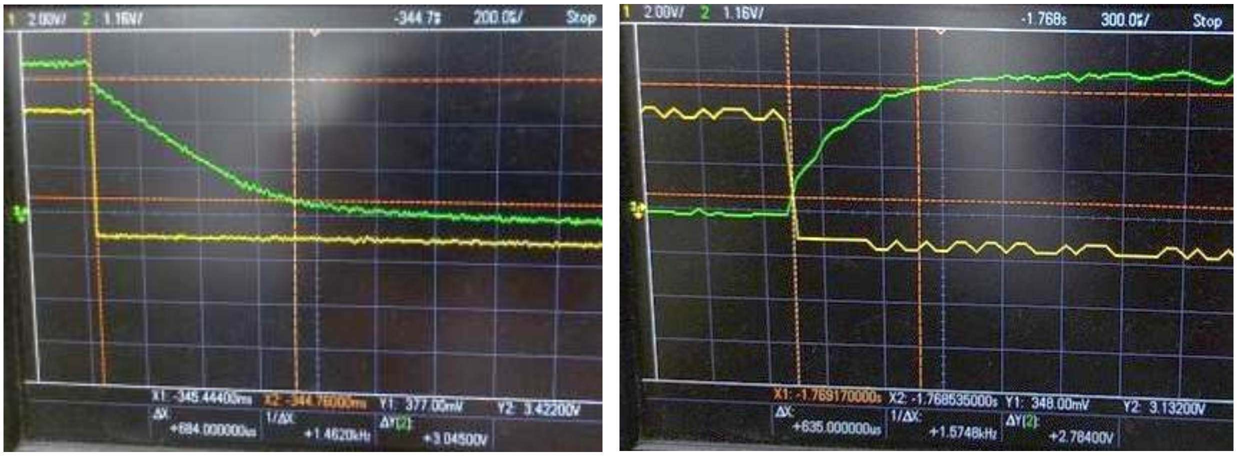


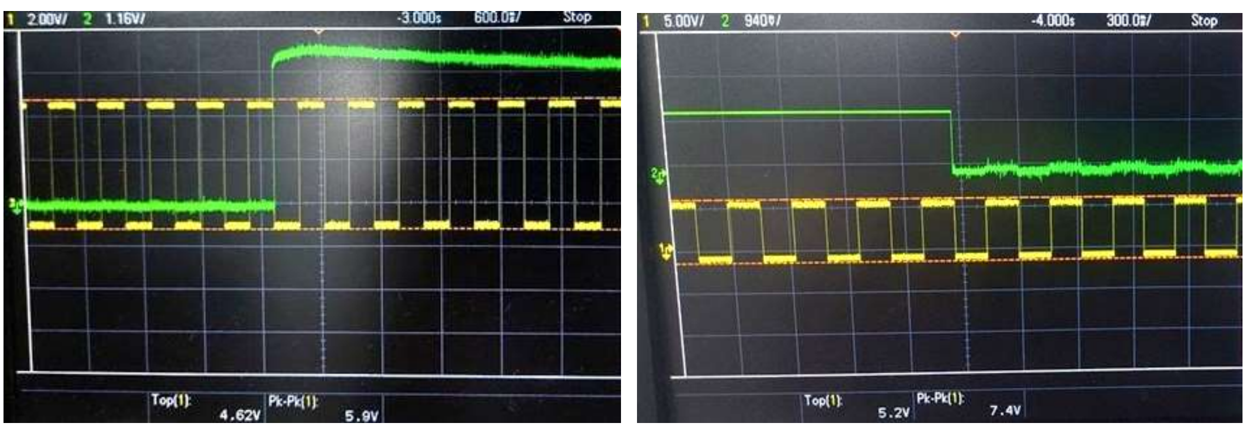
Figure 7. Propagation delay measurement



(a) (b)

Figure 8. Delay measurement: (a) fall delay measurement; (b) rise delay measurement

The yellow channel of Figure 9 (a) shows the square wave input clock signal, representing the people's entrance in each clock. The green channel illustrates the output transition to a LOW state, occurring at approximately the 25th falling edge of the clock. This indicates that 25 individuals have already entered the specific region, marking the onset of crowding. After 8 people leave the area, the entrance gate opens again. This occurs at about the 8th falling edge of the clock, where the output is triggered to reopen the gate, as in Figure 9 (b). The threshold of 8 people is chosen to prevent the gate from opening and closing repeatedly, ensuring smoother operation and avoiding unnecessary switching. The performance metrics are shown in Table 1.



(a) (b)

Figure 9. Entrance gate closure triggers: (a) 25 people entered the area; (b) 8 people left the area

Table 1. Performance metrics of the proposed crowd control system

Parameter	**Measured Value**	**Description**
Counting Rate	Up to 3 persons/second	The maximum number of people counted per second
Response Time	445 µs	Total propagation delay from input trigger to gate activation
Rise Delay	635 µs	Time taken for the output to transit from LOW to HIGH
Fall Delay	684 µs	Time taken for the output to transit from HIGH to LOW
Power Consumption	1.8 W	Average power used during operation

The logic analyzer was configured with A0 connected to the entrance clock input, while channels A1 to A6 were connected to the subtractor outputs that indicate the count reaching 25, as shown in the Proteus simulation setup (Bhuyan and Hasan, 2020) of Figure 10. Channel A7 was connected to the system output, confirming that at the exact 25th count, the gate closes (logic HIGH).

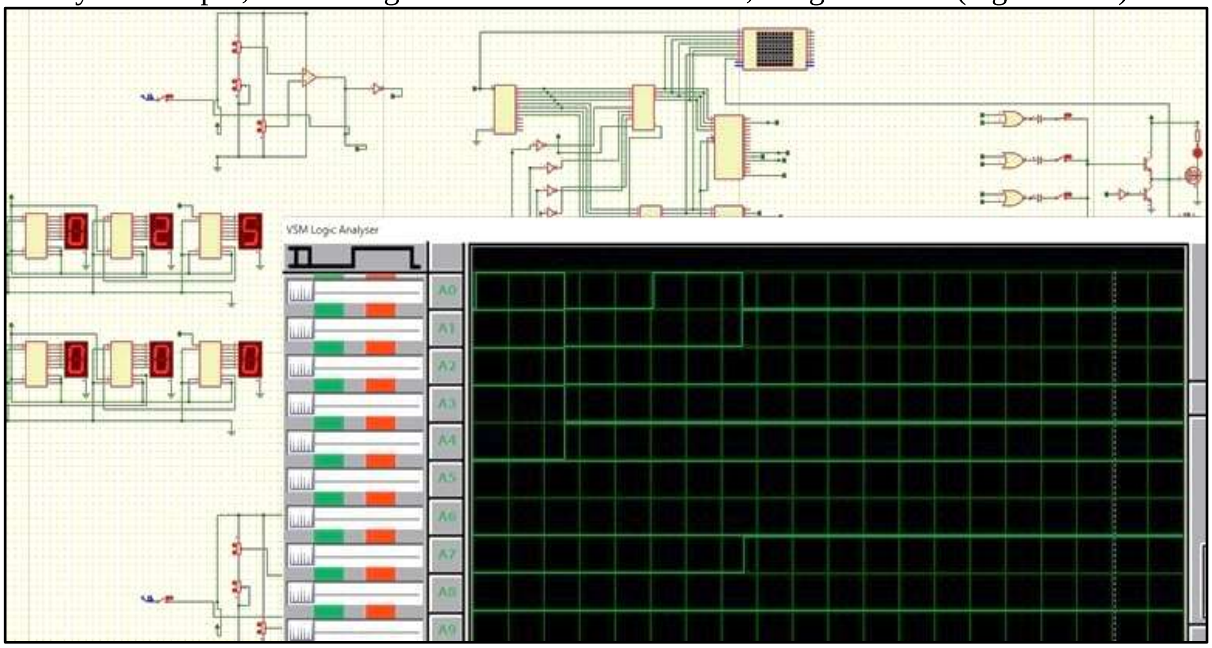


Figure 10. Simulation of the situation, crowd flow reaching threshold (25 persons)

The logic analyzer indicates that the gate reopens after 8 people exit the area, as shown in the Proteus simulation setup of Figure 11. The display shows 14 people exiting, and the output is still logic LOW, indicating that the gate remains open.

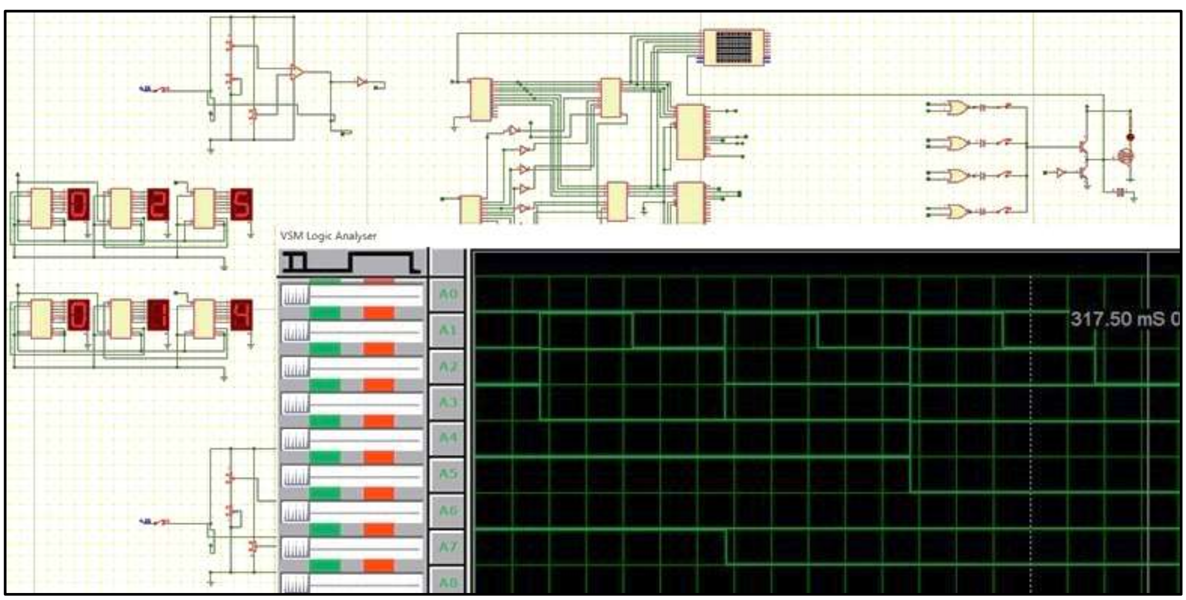


Figure 11. Simulation of the situation, gate reopening response based on the exit threshold

The breakdown of the cost analysis is shown in Table 2.

Table 2. Performance metrics of the proposed crowd control system

SL	Components	Quantity	Unit Price (৳)	Total Price (৳)	USD ($)
1	CD4026BE	6	50	300	2.47
2	74LS283	2	38	76	0.62
3	4040B	2	26	52	0.43
4	74LS04	11	30	330	2.71
5	74LS154	2	185	370	3.04
6	74LS02	4	28	112	0.92
7	LM324	1	15	15	0.61
8	BC547	2	4	8	0.066
9	IRF540N	1	57	57	0.47
10	1N4001	4	3	12	0.099
11	LED	3	5	5	0.041
12	Potentiometers	1	25	25	1.18
13	Resistors	3	2	6	0.041
14	Capacitors	3	10	30	0.28
15	LASER	2	26	52	0.58
16	SMPS	2	460	920	7.57
17	7805	2	15	30	0.28
			Total Price	**2370**	**19.78**

The feature and performance comparison of our system with the existing system is shown in Table 3. It shows the effectiveness of our system.

Table 3. Comparison of features and performance parameters with the existing system

Feature Parameter	Cho et al., 2018	Hashimoto et al., 1998	Durán-Polanco et al., 2021	Proposed System
Core Technology	Vision Based	Pyroelectric IR array	Application Based	Laser and LDR sensor-based digital circuits
Processing Unit	Raspberry Pi	Custom ASIC + Signal Processor	Server based	None (pure hardware logic)
Delay	0.26 s/frame	Low (sensor-triggered)	Not required	500 μs
Maintenance Requirement	Software updates, retraining	Very low	High, software updates	Very low, no software updates
Approx. Unit Cost ($)	Not mentioned	Not mentioned	Not mentioned	~19.78
Crowd Controlling	Not available	Not available	Not available	Available

Conclusion

The proposed crowd management system demonstrates an effective approach to controlling and monitoring occupancy in confined spaces using low-cost sensors and simple logic circuits. The implementation successfully detects entry and exits events, maintains a real-time count of individuals, and activates gate or alert mechanisms when thresholds are exceeded. Performance evaluation shows fast response times and stable operation with minimal ripple. Low power consumption confirms that the system is practical for small to medium-scale applications. Despite these advantages, the system has some limitations. It relies on direct line-of-sight detection, which may reduce accuracy in highly dynamic or obstructed environments. The current implementation handles moderate crowd densities, but extremely high-density scenarios may require more advanced detection mechanisms. Future work could focus on integrating wireless communication, IoT-based monitoring, and application-specific integrated circuits.

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References

Ali, A., Ayub, N., Shiraz, M., Ullah, N., Gani, A., & Qureshi, M. A. (2021). Traffic efficiency models for urban traffic management using mobile crowd sensing: A survey. *Sustainability*, 13(23), 13068. https://doi.org/10.3390/su132313068.

Alkhadim, M., Gidado, K., & Painting, N. (2018). Perceived crowd safety in large space buildings: The confirmatory factor analysis of perceived risk variables. *Journal of Engineering, Project, and Production Management*, 8(1), 22-39. https://doi.org/10.32738/JEPPM.201801.0004.

Assem, A. (2024). Smart staircase: Interactive design for social distancing and crowd management. *Journal of Engineering Science, Part E: Architectural Engineering*, 52(6), 739-756. https://doi.org/10.21608/jesaun.2024.308334.1359

Bhuyan, M. H. (2007). Finite State Machine-Based Directional Counter Design Using VHDL. *Journal of Bangladesh Electronics Society*, 7(1-2), 45-53. https://www.researchgate.net/publication/287975558

Bhuyan, M. H. and Hasan, M. (2020). Design and Simulation of Heartbeat Measurement System using Arduino Microcontroller in Proteus. *International Journal of Biomedical and Biological Engineering*, 14(10), 350-357. https://www.researchgate.net/publication/344908351

Bong, D. B. L., Ting, K. C., & Lai, K. C. (2008). Integrated approach in the design of the car park occupancy information system (COINS). *IAENG International Journal of Computer Science*. 35(1), 1-7. https://www.iaeng.org/IJCS/issues_v35/issue_1/IJCS_35_1_02.pdf.

Chen, Y., Gundu, K., Zaidi, Z., & Zhao, M. (2023). LiDAR-based outdoor crowd management for smart campus on the edge. *Computer Vision and Pattern Recognition*. 1-9 https://doi.org/10.48550/arXiv.2311.18077.

Cho, S. I., & Kang, S.-J. (2018). Real-time people counting system for customer movement analysis. *IEEE Access*, 6, 55264–55272. https://doi.org/10.1109/ACCESS.2018.2872684.

Durán-Polanco, L., & Siller, M. (2021). Crowd management COVID-19. *Annual Reviews in Control*, 52, 465-478. https://doi.org/10.1016/j.arcontrol.2021.04.006.

Hashimoto, K., Kawaguchi, C., Matsueda, S., Morinaka, K., & Yoshiike, N. (1998). People-counting system using multisensing applications. *Sensors and Actuators A: Physical*. 66(1-3), 50-55. https://doi.org/10.1016/S0924-4247(97)01715-9.

Rusek, R., Melendez Frigola, J., & Colomer Llinas, J. (2022). Influence of occupant presence patterns on energy consumption and its relation to comfort: A case study based on sensor and crowd-sensed data. *Energy, Sustainability and Society*. 12:13, 1-14. https://doi.org/10.1186/s13705-022-00336-6.

Tirachini, A., Hensher, D. A., & Rose, J. M. (2013). Crowding in public transport systems: Effects on users, operation, and implications for the estimation of demand. *Transportation Research Part A: Policy and Practice*, 53, 36-52. https://doi.org/10.1016/j.tra.2013.06.005.

Vega-Barbas, M., Álvarez-Campana, M., Rivera, D., Sanz, M., & Berrocal, J. (2021). AFOROS: A low-cost Wi-Fi-based monitoring system for estimating occupancy of public spaces. *Sensors*, 21(11), 3863. https://doi.org/10.3390/s21113863.

Virgona, A., Kirchner, N., & Alempijevic, A. (2015). Sensing and perception technology to enable real-time monitoring of passenger movement behaviors through congested rail stations. *Proceedings of the Australasian Transport Research Forum 2015*. Sydney, Australia. http://www.atrf.info/papers/index.aspx.