

Smart Car Park System

How can Technology be used to design a smart car park system that displays real-time information on available spaces?

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1. Introduction

Problem Statement

Traditional car parks offer little to no information on the used capacity until the driver enters and is looking for a space. Those that do offer information typically rely on a barrier or a human and only track if the car park is full.



Aim

Design, build and evaluate a prototype smart car park system using low-cost components and demonstrate that effective smart parking technology is achievable without complex and expensive systems.

Real-world Case studies

NCP/Clearview

Uses entry/exit loop counters to track the number of cars in each car park. Cost-effective but lacks per-bay precision. Also subject to counting errors, which can build up over time.

Westminster City Council

Deployed over 3000 parking bays with infrared sensors. Gained a 2.3% increase in payments but was quickly decommissioned due to unsustainable battery maintenance costs.

Gap In The Market

Current Smart car parking systems are too expensive for everyday urban car parks, rely on a single-sensor approach, and have unsustainable power solutions. This project addresses all three of these problems directly.

Ethical And Social Considerations

Privacy: Sensor-based systems avoid capturing identifiable information, which eliminates GDPR considerations.

Accessibility: Real-Time availability is especially valuable for drivers with mobility issues who need disabled bays.

Inclusion: By demonstrating that low-cost smart parking is viable, this project makes the technology accessible to smaller operators and the communities they serve.

2. System Design

Sensor Selection

Ultrasonic sensors were selected for their low cost and simple TRIG/ECHO interface. For the final design, magnetic sensors would be incorporated for their reliability and weather-independent detection.

Sensor	Cost	Accuracy	Selected
Camera	£150	★★★★★	✗
Ultrasonic	£3	★★★★☆	✓
Magnetic	£5	★★★★★	✓
Infrared	£6	★★☆☆☆	✗
Radar	£120	★★★★★	✗

Hardware Design

PIC16F877A	Central Microcontroller – 5V requires no voltage change, 33 I/O pins provides scalability, handles all LED and LCD output
3x HC-SR04	Ultrasonic sensor, side-mounted on a bollard, which provides easier deployment. JSN-SR04T could be used in full deployment as it is waterproof
JM164A LCD	16x4 display at the entrance, 4-bit mode, 6 pins on Port D. Potentiometer for contrast. Offers enough room for all important information.
3x LED	220Ω resistor which then goes to ground. On = free space, Off = occupied, Flashing = fault
4.7K and 10K resistor	10kΩ pull-up resistor prevents accidental PIC resets from electrical noise. 4.7kΩ pull-up resistor on RA4 since its an open drain pin and cannot drive high without the resistor.
USB Power Bank	5V supply for prototype. Mains buried cabling intended for full deployment

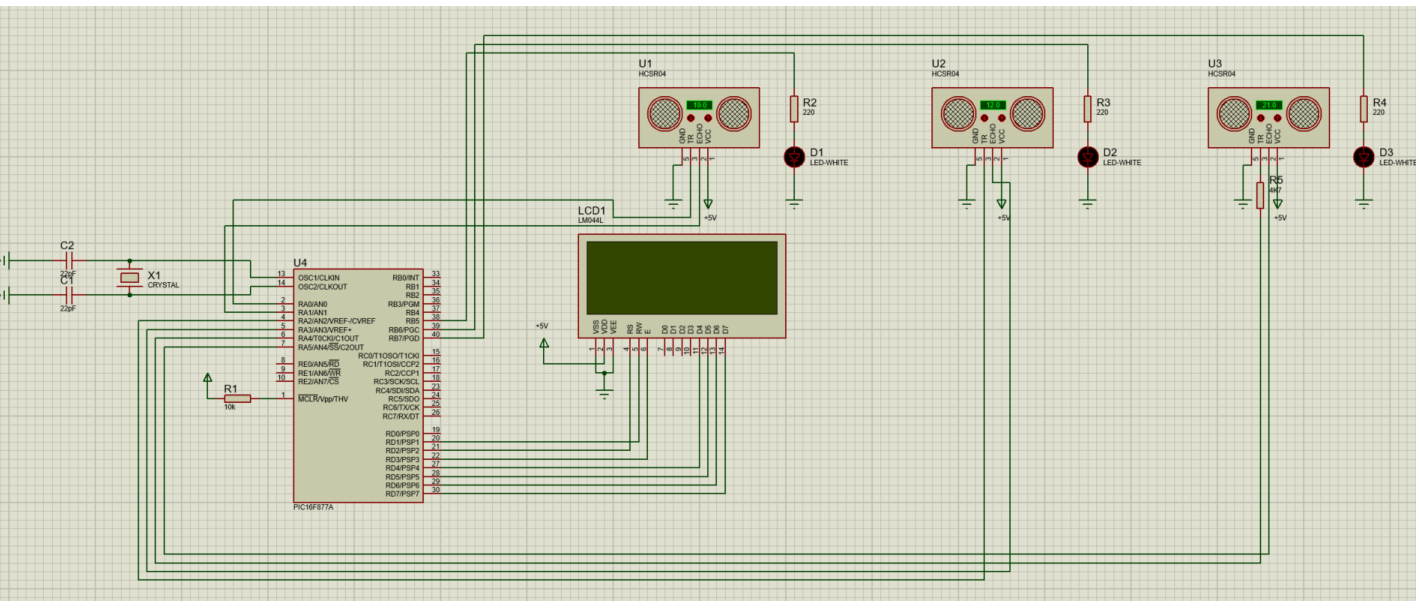
Pin Assignment

Port	Pins Used	Function
Port A	RA0 - RA5	Ultrasonic sensor, Trigger(0, 2,4), Echo(1, 3, 5)
Port B	RB5 - RB7	LED outputs
Port C	✗	Not used, allows for future scalability
Port D	RD2 - RD7	LCD, (RS, E, D4 - D7)
Pin1	MCLR	10KΩ pull-up to 5V

Software Design

Initialisation Port directions set, ADC disabled on Port A (critical), all bays set EMPTY, LCD init, startup flash x3
Sensor Reading Trigger pulse sent, echo duration measured via Timer1, distance = count÷58 (cm). 50ms delay between sensors prevents cross-interference
Occupancy Logic Distance < 20 cm → OCCUPIED. Return 255 = fault. 5 consecutive faults = FAULT state. Valid reading resets the fault counter
Fault Tolerance Fault state activates flashing LED. System continues monitoring other bays. Auto-recovers when valid signal restored
LCD Update Line 1: header. Line 2: Available X/3. Lines 3–4: bay status (FREE/FULL/FAULT) via direct HD44780 RAM writes to 0x14 and 0x54. Full design could incorporate how many normal bays, accessible bays and EV charging bays are free

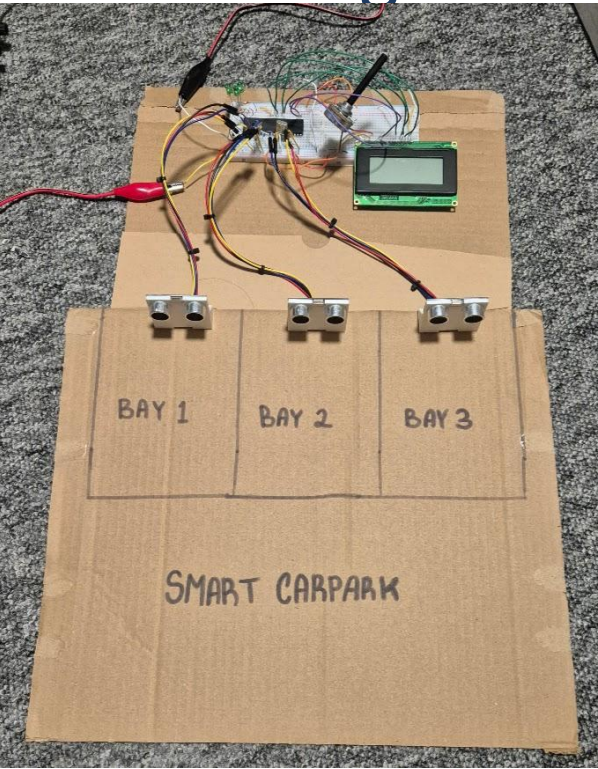
Proteus Schematic



3. Implementation & Testing

Build Notes

The prototype was constructed around the PIC16F877A. A breadboard design was chosen as it allows for flexibility and easy changes during testing.



Key Issues Identified and Solved

! RA4 Open Drain - Pin RA4 can't drive high independently, A 4.7KΩ pull-up resistor is added to achieve 5V. Without this, bay 3 will always read as a fault

! LCD Lines 3 & 4 - lcd_gotoxy() only supports lines 1 and 2 Direct HD44780 RAM address writes needed for lines 3 (0x14) and 4 (0x54)

! Sensor Timing - Proteus required a divisor of 1.33μs/cm vs 58μs/cm that's required in real-world practice. 58μs/cm was kept in the final code for deployment

! ADC Disabled - Port A defaults to analogue mode on the PIC16F877A. setup_adc_ports(NO_ANALOGS) is essential or else the echo pins will return 0

Simulation Testing (Proteus)

Test	Description	Expected Result	Actual Result
1	All bays empty on startup	All LEDs on, LCD shows Available: 3/3	✓
2	Bay 1 occupied	Bay 1 LED off, LCD shows Available: 2/3	✓
3	All bays occupied	All LEDs off, LCD shows Available: 0/3	✓
4	False reading triggered	Fault bay LED flashes, LCD shows FAULT or FA	✓
5	Startup LED flash	All LEDs flash 3 times before normal operation	✓
6	All three states	LCD shows correct count and individual statuses	✓
7	Bay 3 Free	Bay 3 LED on, LCD shows Available: 1/3	✓
8	LCD displaying	LCD displays 'Smart Car Park System Starting'	✓
9	LCD displaying all	LCD displays 'OC', 'FA' and 'FR' simultaneously	✓

Additional Verified Testing

- Fault counter retains last known status for 5 readings before flagging to prevent false alarms
- Flash state toggles every loop (~350–400ms cycle) — clearly visible without being distracting
- 50ms inter-sensor delay confirmed sufficient to prevent acoustic cross-interference
- System auto-recovers from fault state when valid reading is restored - no manual reset needed

Physical Testing

Physical testing of the completed prototype was planned following the resolution of compiler issues encountered during development. Results will be presented live at the viva examination via a recorded video demonstrating normal occupancy detection, fault triggering, and LCD output across all three bays simultaneously. The physical prototype has been verified to power on, complete the startup sequence and respond to sensor inputs during informal testing sessions.

Evaluation Against Requirements

Requirement	Met?
Detect bay occupancy accurately	✓
LED status indicators (on/off/flash)	✓
Startup LED confirmation flash	✓
Fault detection after 5 failures	✓
LCD availability count accurate	✓
Low power operation	✓
Within budget constraints	✓

4. System Design

Achievements

All 9 simulations passed – core logic validated across all operating states	✓
Fault detection and automatic recovery implemented – clear signals to avoid confusion	✓
Side-mounted bollard configuration demonstrates technology works without a ceiling	✓
JM164A LCD displays spaces at entrance – avoids unnecessary entrance to the car park	✓
Low-cost components prove system is viable for everyday car parks	✓

Limitations

! Side-mounted calibration - wider beam angle at ground level increases risk of adjacent bay interference. Calibration is required at the site before deployment.

! Prototype Scale - A three-bay system prototype proves the core functions work but isn't tested at scale. 50+ bays could require longer processing times

! Physical testing pending - Due to compiler and Pickit issues, physical testing has been delayed until the viva. Simulation results validate logic

Future Work

HMC5883L Magnetic Sensor - Add secondary detection via I2C. Enables full AND logic - both sensors must confirm before the bay is marked occupied. Custom IP67 ABS housing designed for surface or flush mount

Mains power infrastructure - Buried mains cabling for permanent deployment - eliminates battery maintenance burden that caused Westminster scheme failure

Distributed Architecture - At full scale deployment, per-bay microcontroller nodes transmit wirelessly to central controller. Removes wiring complexity of single PIC approach

LCD Signage - At full-scale deployment, the LCD will be able to show available spaces, available accessible spaces, available children's spaces and available EV charging spaces

Conclusion

This project set out to answer the question: how can technology be used to design a smart car park system that displays real-time information on available spaces?

The answer is clear. A functional, cost-effective and fault-tolerant smart parking system is achievable using the PIC16F877A, HC-SR04 ultrasonic sensors and a JM164A LCD - without the complexity or expense that has historically made smart parking inaccessible to smaller operators, such as cameras.

All nine simulation tests passed. The fault detection logic performs as intended. The side-mounted configuration demonstrates that the technology works beyond its typical deployment context. The design provides a well-documented path for future development with magnetic sensors, mains power and distributed architecture.

Smart parking does not have to be expensive, complex or reserved for premium sites. This project delivers proof of that.



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