

TABLETOP FANTASY FOOTBALL

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1. Introduction

1.1 Problem

Fantasy football has become a popular way for sports fans to compete with friends while following professional football. The Fantasy Sports and Gaming Association reports that more than 53 million people participate in fantasy sports, demonstrating the significant role fantasy sports play in modern sports entertainment [1]. However, the traditional fantasy football experience is primarily designed around digital platforms and long-term leagues. Players typically need to create or join a league, coordinate a draft with several participants, select and manage a roster, and remain engaged throughout an entire NFL season. This structure works well for dedicated fantasy players but makes it difficult for people who want to casually compete with a friend while watching football for only a single afternoon.

For example, two friends watching NFL games together may want to select players and compete based on their performances that day. With existing fantasy football platforms, doing so generally requires interacting with a website or mobile application and configuring a league or contest before gameplay begins. This also means that much of the fantasy experience occurs individually through phones or computers even when participants are physically together. Although physical scoreboards can display sports information and traditional board games can provide face to face interaction, these systems generally do not combine physical gameplay with automatically updated statistics from live NFL games. Our project addresses this gap by creating a more immediate and tangible form of fantasy football that combines live sports data with an interactive tabletop game. The primary societal relevance of the project is therefore social and cultural: it provides another way for people to interact face to face while participating in a form of sports entertainment already used by millions of people.

1.2 Solution

Our solution is a battery powered Tabletop Fantasy Football system that allows two users to play a head-to-head fantasy football matchup using physical player cards while watching live NFL games. The board will be divided into two player areas, with dedicated locations for each user's lineup. Each lineup will contain five required positions - one quarterback, one running back, one wide receiver, one tight end, and one defense. If the NFC reader spacing and board dimensions permit, a sixth FLEX position will be included that can accept an additional eligible player. Each physical player card will contain a passive NFC tag that identifies the corresponding NFL player. When cards are placed onto the board, NFC reader circuitry will detect the cards and allow the system to determine each user's active lineup. This creates a physical interaction like a tabletop game rather than requiring users to manage the matchup through a phone or computer.

A microcontroller with Wi-Fi connectivity will serve as the primary controller for the board. Live NFL player statistics will be obtained using the SportRadar NFL API, which provides player and team level game statistics and supports real time updates while games are in progress [2]. The system will use these statistics to calculate each user's fantasy score according to configurable scoring rules and automatically update the matchup throughout the games. A display on the board will show information

such as the current scores and relevant game or player information. RGB LEDs located around the player card positions will provide visual feedback when important events occur, while a speaker will provide audio feedback for events such as touchdowns and field goals. Physical controls on the board will allow users to start a matchup and adjust settings such as brightness and volume. All normal gameplay will therefore be possible directly through the tabletop system without requiring a phone or companion application.

1.3 Visual Aid

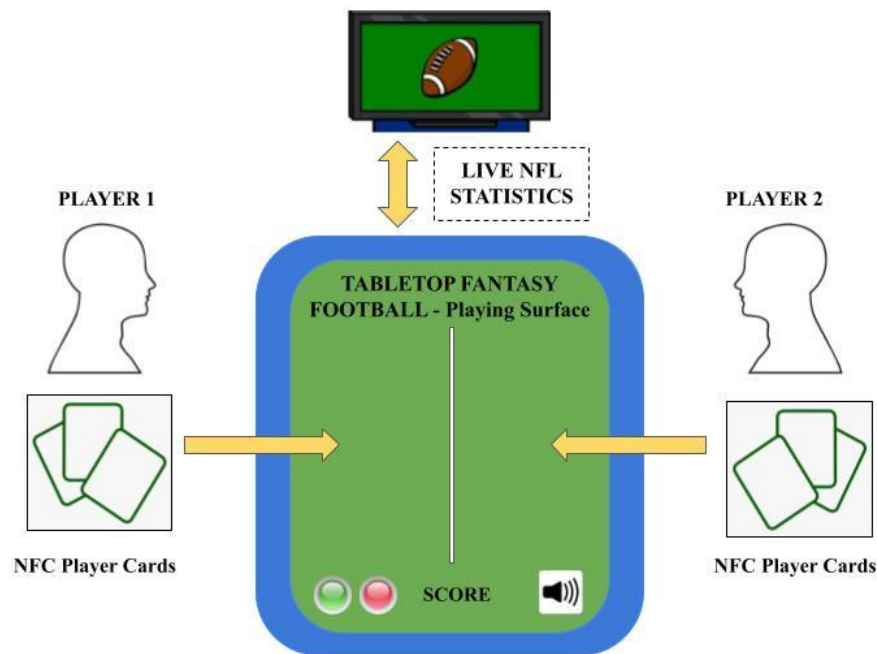


Figure 1: Intended use of the tabletop fantasy football system, where two players use NFC-enabled player cards to compete in a matchup that updates automatically using live NFL statistics.

1.4 High-Level Requirements

Since the primary problem addressed by this project is the friction associated with traditional fantasy football leagues, the system must provide a convenient, responsive, and gamified user experience. As a result, high-level requirements place importance on latency, setup time, and detection accuracy.

- 1) The system shall detect and identify an NFC player card placed within a designated roster position within 5 seconds, with a success rate of at least 95%.
- 2) The system should update the displayed fantasy score within 15 seconds of the corresponding player-statistic update becoming available from the live NFL data source for at least 90% of tested scoring events.
- 3) The system shall operate continuously for at least 90 minutes of active gameplay without requiring a manual reset or losing the current lineup, fantasy score, or matchup state.

2 Design

2.1 Block Diagram

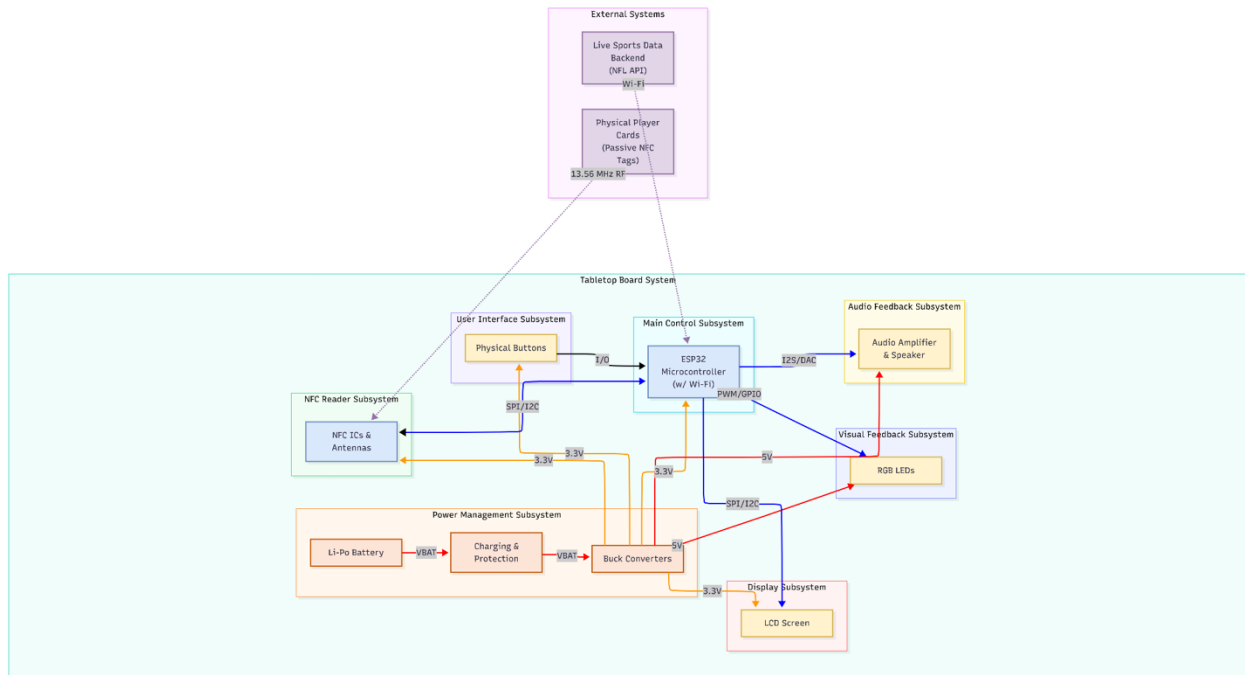


Figure 2: Block diagram of the system, showing the major subsystems, power connections, and communication interfaces.

2.2 Subsystem Overview

2.2.1 Main Control Subsystem

The Main Control Subsystem serves as the central processing unit of the tabletop system and will be implemented using an ESP32 microcontroller with integrated Wi-Fi capability. The ESP32 will receive player-identification information from the NFC Reader Subsystem, read user inputs from the User Interface Subsystem, communicate with the live sports-data backend through Wi-Fi, and control the Display, Visual Feedback, and Audio Feedback Subsystems. The microcontroller will maintain the current lineup for both users, validate that each lineup contains the required player positions, receive updated NFL statistics, calculate fantasy scores according to the selected configurable scoring system, and determine when events such as touchdowns, catches, fumbles, or field goals should trigger feedback. Communication with the other subsystems will occur through interfaces including SPI/I²C, GPIO/PWM, and I²S or DAC depending on the final peripheral selections.

2.2.2 NFC Reader Subsystem

The NFC Reader Subsystem identifies the physical player cards placed on the tabletop board. Each card contains a passive NFC tag corresponding to a specific NFL player. A dedicated NFC reader and antenna will be located beneath each player-card position so that each position can be monitored independently. Each side of the board will support five required positions - quarterback, running back, wide receiver, tight end, and defense - with a sixth FLEX position included if antenna spacing and board dimensions permit. The NFC readers will communicate with passive tags using 13.56 MHz RF and will transfer the

detected player identifiers to the ESP32 through SPI or I²C. The most important design consideration for this subsystem is maintaining sufficient range to reliably detect a card in its intended zone while preventing an adjacent reader from detecting the same card.

2.2.3 User Interface Subsystem

The User Interface Subsystem consists of physical buttons located on the tabletop board. These controls allow the users to operate the system without requiring a phone or external application. Buttons will be used for actions such as beginning a matchup, confirming lineup selections, and adjusting user settings such as audio volume. The buttons will connect directly to ESP32 digital I/O pins, and the microcontroller will perform software debouncing to prevent a single physical press from being interpreted as multiple inputs. The subsystem therefore provides the primary means of user control while maintaining the project's goal of operating as a self-contained tabletop device.

2.2.4 Display Subsystem

The Display Subsystem consists of a small LCD screen controlled by the ESP32 through an SPI or I²C interface. Its primary purpose is to display the current fantasy score for both users throughout the matchup. When updated player statistics are received from the backend and new scores are calculated, the Main Control Subsystem will send the corresponding information to the LCD. The display provides a persistent indication of the matchup state, while the LED and audio systems provide temporary feedback for individual football events.

2.2.5 Visual Feedback Subsystem

The Visual Feedback Subsystem consists of RGB LEDs associated with the player-card positions on the board. The ESP32 will control the LEDs through GPIO and PWM signals, allowing individual channels to change color, brightness, or pulse patterns. When the system receives an updated player event such as a touchdown, catch, fumble, or other relevant play, the ESP32 will identify the card corresponding to that player and activate the associated LEDs. This subsystem converts changes in live NFL statistics into visible physical reactions on the board and is one of the primary features distinguishing the project from a conventional fantasy-football application.

2.2.6 Audio Feedback Subsystem

The Audio Feedback Subsystem provides audible responses to important events during a matchup. The subsystem will consist of an audio amplifier and speaker controlled by the ESP32 using an I²S or DAC output. When an event such as a touchdown, field goal, or other major scoring event is detected, the Main Control Subsystem will command the audio subsystem to produce the appropriate sound. Audio feedback operates alongside the RGB LED subsystem so that important events can produce both visual and audible responses.

2.2.7 Power Management Subsystem

The Power Management Subsystem supplies power to all electronics on the tabletop board and allows the device to operate without being continuously connected to an external power source. A rechargeable Li-Po battery will connect to a custom-designed battery-management, charging, and protection circuit. The battery output will then be converted into regulated 3.3 V and 5 V rails using DC-DC converters. The 3.3 V rail will supply low-voltage digital circuitry such as the ESP32, NFC electronics,

and display, while the 5 V rail will supply components requiring the higher voltage, including the visual and audio subsystems as indicated in the block diagram. The custom battery-management circuit will provide charging and protection against conditions such as overcurrent, overvoltage, and excessive discharge. The power subsystem must support at least ninety minutes of continuous operation.

2.2.8 External Interface Subsystem

The external interface subsystem provides the external sources of information that are required for successful operation of the tabletop system, namely live NFL statistics and player identification via NFC player cards. The Live Sports Data Backend retrieves current NFL player statistics via an API and communicates relevant updates to the ESP32 over the board's Wi-Fi connection. Physical player cards contain passive NFC tags that contain a unique identifier for seamless recognition when placed on the board's defined reader zones. The NFC Reader subsystem communicates with these player cards over a pre-defined frequency of 13.56 MHz and passes the detected identifiers to the Main Control Subsystem.

2.3 Subsystem Requirements

2.3.1 Main Control Subsystem

The ESP32 must support simultaneous communication with the NFC, display, user-interface, visual-feedback, and audio subsystems. It must maintain and validate two independent fantasy lineups containing at least five positions per user. It must communicate with the Sportradar-based backend over Wi-Fi and calculate fantasy scores using configurable scoring rules. After updated data is pulled from the backend, the system must calculate the resulting score changes and update the board within 15 seconds. The controller must associate incoming events with the correct player/card position before activating visual or audio feedback.

ESP32 must successfully communicate with the NFC system, LCD, LEDs, audio system, buttons, and Wi-Fi backend. A newly received sports-data update must be processed and reflected by the board within 15 s of receipt.

Verification: Send 100 simulated backend updates containing known player events and timestamp receipt and board response. Verify every update completes within 15 s.

2.3.2 NFC Reader Subsystem

Each active card position must contain a dedicated NFC reader/antenna operating at 13.56 MHz. A correctly positioned player card must be identified with a success rate greater than 95%. A card placed in one designated position must not be incorrectly assigned to an adjacent card position. The subsystem must support at least 10 simultaneous physical positions - five for each user - with the design expandable to 12 positions if FLEX positions are included. The detected tag identifier and associated position must be transferred correctly to the ESP32 over SPI or I²C.

The system must correctly identify a card in its intended position in >95% of placement trials and must not assign that card to an adjacent roster position.

Verification: Perform at least 100 card placements across the designated zones and record correct detections and false neighboring detections.

2.3.3 User Interface Subsystem

Physical button presses must result in exactly one intended logical command after debouncing. Controls must allow the users to begin and operate a matchup without requiring a phone or external application. User input signals must be compatible with the ESP32 digital I/O voltage levels and must not produce floating or undefined logic states when buttons are inactive.

A valid button press must produce exactly one command after debouncing.

Verification: Perform repeated button presses and verify one software event per physical press using serial logging.

2.3.4 Display Subsystem

The LCD must simultaneously display the scores of both users. It must receive updated score information from the ESP32 through SPI or I²C. Any score change resulting from newly received sports data must appear on the display within the overall 15 second system update requirement. The display must operate from the regulated supply provided by the Power Management Subsystem without causing that rail to fall outside its specified tolerance.

The LCD must show both team scores and display a changed score after receiving an updated value from the ESP32.

Verification: Inject known score changes and compare the transmitted value with the displayed value.

2.3.5 Visual Feedback Subsystem

RGB LED channels must be individually controllable by the ESP32 through GPIO/PWM. The subsystem must provide identifiable visual feedback for at least 90% of recognized test events, consistent with the project's existing success criterion. Different colors, brightness levels, or pulse patterns must be producible for events such as touchdowns, catches, and fumbles. Activation of one player position LED must not unintentionally activate another position.

Individual player position LEDs must be independently controllable, and the correct position must respond to at least 90% of injected test events.

Verification: Inject touchdown, catch, and fumble events for known players and record whether the correct LED position responds.

2.3.6 Audio Feedback Subsystem

The amplifier and speaker must accept an audio signal generated or commanded by the ESP32 through I²S or DAC. The subsystem must provide an audible notification for defined major events including touchdowns and field goals. Audio playback must not interfere with microcontroller operation, Wi-Fi communication, or the regulated supply rails.

The speaker must produce the designated audio cue when commanded by the ESP32.

Verification: Inject each supported audio event repeatedly and verify that the expected sound is produced without ESP32 resets or communication failures.

2.3.7 Power Management Subsystem

The subsystem must generate regulated 3.3 V and 5 V rails, each maintained within $\pm 5\%$ of its nominal value during normal operation. The battery and converters must provide sufficient energy for at least 90 minutes of continuous gameplay. The custom BMS must support safe charging of the selected Li-Po battery and prevent operation outside the battery manufacturer's allowable overvoltage, undervoltage, and overcurrent limits. The system must be capable of powering the ESP32 with Wi-Fi active while simultaneously operating the NFC readers, LCD, LEDs, and audio circuitry without causing resets or loss of regulation.

The power subsystem must maintain the required regulated rails during simultaneous normal operation and power the device for at least 90 min. The ESP32 3.3V supply must be capable of supplying at least 500 mA to meet Espressif's recommended supply capability.

Verification: Operate Wi-Fi, NFC polling, LCD, LEDs, and audio simultaneously for 90 min while monitoring rail voltages and checking for resets or abnormal heating. Apply the maximum expected ESP32 load and measure the 3.3V rail with an oscilloscope/multimeter to verify that it remains within the selected voltage tolerance.

2.3.8 External Interface Subsystem

The subsystem must provide the board with both identifiable player information and live NFL statistics. Each player card must contain a unique passive NFC tag readable by the NFC Reader Subsystem. To ensure this connection, a frequency of 13.56 MHz should be utilized for NFC communication. The Live Sports Data Backend must provide statistics updates to the ESP32 over Wi-Fi. These inputs must allow an update of the corresponding fantasy score, display output, and audio output.

NFC Player cards must be uniquely identifiable, with the card detected accurately $>95\%$ of the time within 5 seconds. Backend must provide sufficient data to accurately calculate scoring for all positions.

Verification: Place known NFC cards into designated roster positions and record accuracy and latency of identification. Inject known player-statistic updates and verify they produce the expected score changes. Additionally, operate subsystem during real NFL game to ensure timely updates.

2.4 Tolerance Analysis

One of the largest technical risks in our design is reliably distinguishing between NFC player cards placed in adjacent roster positions. Each player will have five required card positions, with the possibility of adding a sixth FLEX position if sufficient space is available. Therefore, the complete board may contain

between ten and twelve NFC reader antennas. If the readers are positioned too closely together, a reader could detect a card intended for a neighboring position. On the other hand, excessive spacing would make the tabletop system unnecessarily large. The purpose of this analysis is to determine whether the required number of NFC positions can reasonably fit on the board while maintaining sufficient separation between neighboring cards.

NFC reader systems operate at 13.56 MHz, and the actual detection distance depends strongly on antenna size, antenna tuning, tag geometry, and power supply. As a reference point, NXP specifies a typical operating distance of approximately 50 mm for the PN532 in reader/writer mode, depending on the antenna design and tuning. NXP's antenna design documentation also emphasizes that the antenna and matching network must be tuned for the particular reader implementation. Because our final NFC IC and antenna geometry have not yet been selected, 50 mm will be used as a conservative preliminary design reference rather than as a guaranteed read distance.

For an initial board layout, we will assume each physical player card occupies approximately 64 mm × 89 mm, like the size we intend to use for the final player cards. We will initially place 12 mm of spacing between adjacent card locations. This results in a center-to-center horizontal distance of

$$64 \text{ mm} + 12 \text{ mm} = 76 \text{ mm}$$

between neighboring NFC tags.

If the card is approximately 10 mm above the reader antenna due to the thickness of the board, card holder, and enclosure, the approximate straight-line distance from one reader antenna to the center of the tag in the neighboring position is

$$d = \sqrt{(76 \text{ mm})^2 + (10 \text{ mm})^2}$$
$$d \approx 76.7 \text{ mm}.$$

This distance is substantially greater than the approximately 50 mm typical operating distance used for the preliminary analysis. Therefore, the initial geometry provides a reasonable starting point for preventing one active reader from detecting the card centered over an adjacent reader. This calculation does not guarantee that interference will be eliminated because NFC magnetic fields depend on antenna geometry and orientation rather than only straight-line distance. The final spacing will therefore be experimentally verified.

The same dimensions can be used to determine whether five or six cards will physically fit on each side of the tabletop. For five cards with four 12 mm gaps, the required width is

$$5(64) + 4(12) = 368 \text{ mm} \approx 14.5 \text{ in}.$$

For six cards with five gaps, the required width becomes

$$6(64) + 5(12) = 444 \text{ mm} \approx 17.5 \text{ in.}$$

Therefore, even the six-card configuration can fit within a tabletop board approximately 18 inches wide. Assuming one 89 mm deep row for each player's cards, approximately 100 mm of space between the two player areas for the LCD, speaker, buttons, and supporting electronics, and approximately 15 mm of outer margin on each side, the required board depth is approximately

$$89 + 100 + 89 + 30 = 308 \text{ mm} \approx 12.1 \text{ in.}$$

The preliminary six card design would therefore occupy approximately 18 in × 12 in, which is a reasonable size for a tabletop game. The five-card design could be reduced to approximately 15 in × 12 in. The center region also provides space for the LCD, speaker, and user interface buttons without reducing the separation between NFC player positions.

To further reduce interference, the NFC readers will be polled sequentially, so only one reader antenna is actively attempting to communicate with a card at a given time. After the hardware is assembled, the calculated spacing will be verified experimentally. A player card will be placed at multiple locations and orientations within each designated zone while the intended and adjacent readers are monitored. The intended position must successfully identify the card in greater than 95% of trials, while adjacent positions must not incorrectly assign the card. If adjacent detections occur, the antenna spacing, reader power, antenna geometry, or matching network will be adjusted before the final board layout is selected.

3. Ethics, Safety, and Societal Impact

3.1 Considerations

The design of the "Tabletop Fantasy Football" project adheres to the ethical principles established in the IEEE Code of Ethics and the ACM Code of Ethics. To uphold the ACM Code of Ethics regarding the responsible use of computing resources, the system will access third-party sports data exclusively through authorized API channels. To respect data licensing agreements and backend providers, the software will be designed to avoid over-requesting data by implementing responsible polling intervals, and it will ensure that proprietary API keys are securely managed and never exposed to the end-user.

Furthermore, the integration of Wi-Fi and 13.56 MHz NFC technology introduces specific digital security and privacy considerations. The system will securely handle any local Wi-Fi network credentials required to bring the board online, ensuring user network data is not exposed or stored improperly. Additionally, the passive NFC tags embedded in the player cards will only store non-sensitive, unique player identifiers rather than any personal user information. By prioritizing responsible resource usage and data protection, the project aligns with professional engineering standards.

3.2 Safety and Applicable Standards

The device's reliance on battery power makes ensuring user safety and preventing physical harm a primary ethical obligation. To mitigate the risks of electrical shock or thermal run away, the power subsystem will incorporate charging and battery protection circuitry compliant with industry safety standards. The hardware will be designed to operate at low voltages, utilizing proper insulation and PCB trace routing to prevent overheating.

Additionally, because the device uses wireless communication to fetch live sports data over Wi-Fi and read physical player cards via NFC, it will comply with FCC Part 15 regulations regarding intentional and unintentional radio frequency emissions. To prevent the NFC readers from generating excessive RF noise or interfering with external electronics, the system will utilize proper tuning and polling of the reader zones. By prioritizing hardware safety and RF regulatory compliance, the project aligns with campus laboratory safety policies.

3.3 Societal, Economic, Environmental, and Global Impact

The "Tabletop Fantasy Football" system shifts the typically isolating, fantasy sports experience into an interactive, face to face event that lowers the barrier to entry for casual players. Economically, the device combines digital sports and physical board game markets, creating a category of interactive products. To address the environmental impact of waste from this system, environmentally friendly part will be used when possible. Finally, while the initial focus is the NFL, the system's underlying architecture, which uses physical NFC tokens to trigger live API data, is scalable and can be easily adapted for other sports leagues like the NBA or Premier League.

References

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