Review Paper on RFID Systems: Embedded Software and Hardware Design Review

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9. References

- ISO/IEC 18000 RFID Standards
- IEEE Research Papers on RFID Advancements
- NXP RFID Datasheets & Resources

1. Introduction

1.1 What is RFID?

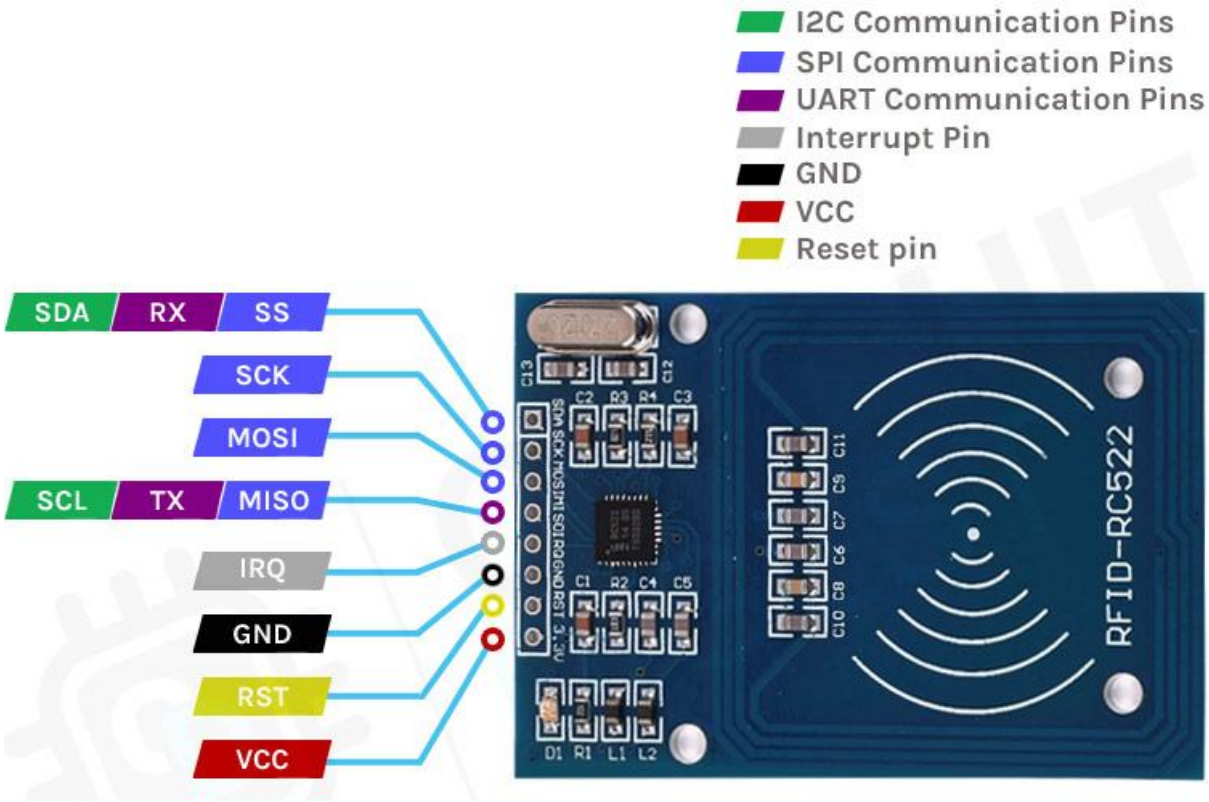
RFID (Radio-Frequency Identification) is a wireless technology that uses radio waves to identify and track objects, animals, or people. It consists of two main components:

- **RFID Tag** (attached to the object)
- **RFID Reader** (scans the tag and retrieves data)

Unlike barcodes, RFID does not require line-of-sight scanning and can read multiple tags simultaneously.

1.2 Scope and Objectives of the Review

This report explains:
✓ How RFID works in simple terms
✓ Different types of RFID and their uses
✓ Hardware & software components
✓ Real-world applications & challenges
✓ Future trends in RFID



2. RFID Technology Overview

2.1 Working Principle of RFID

1. **Reader emits radio waves** via an antenna.
2. **Tag receives power** (passive tags) or transmits data (active tags).
3. **Tag sends back stored data** (e.g., unique ID) to the reader.
4. **Reader processes data** and sends it to a computer or cloud.

2.2 RFID System Components

Component	Function
Tag	Contains a microchip + antenna (stores data)
Reader	Scans tags and processes data
Antenna	Sends/receives signals between tag & reader
Middleware	Software that filters and manages RFID data

2.3 RFID Types

Type	Power Source	Range	Use Case
Passive	Powered by reader	Up to 10m	Inventory tracking
Active	Battery-powered	Up to 100m	Vehicle tracking
Semi-Passive	Battery for sensor, reader powers comm.	Medium	Temperature monitoring

2.4 RFID Frequency Bands

Frequency	Range	Common Use
LF (125-134 kHz)	Short (~10cm)	Animal tracking
HF (13.56 MHz)	Medium (~1m)	NFC, access cards
UHF (860-960 MHz)	Long (~10m)	Supply chain, retail
Microwave (2.45 GHz)	Very long (~30m)	Toll collection

3. Hardware Components Deep-Dive

3.1 RFID Tags

- **IC (Integrated Circuit)** – Stores data (e.g., ID, product info).
- **Antenna** – Receives power and transmits data.
- **Memory Types**:
    - **Read-Only (RO)** – Pre-written (e.g., serial numbers).
    - **Read-Write (RW)** – Can be updated (e.g., logistics tracking).

3.2 RFID Readers

- **Processor** – Decodes tag data.
- **RF Module** – Handles wireless communication.
- **Interface Ports** – USB, Ethernet, Wi-Fi for data transfer.

3.3 Power Supply & Efficiency

- Passive tags rely on **electromagnetic induction** from the reader.

- Active tags use **batteries** for long-range communication.

3.4 Antenna Design & Placement

- **Larger antenna = longer range.**
- **Metal & liquids interfere with signals** → must be placed carefully.

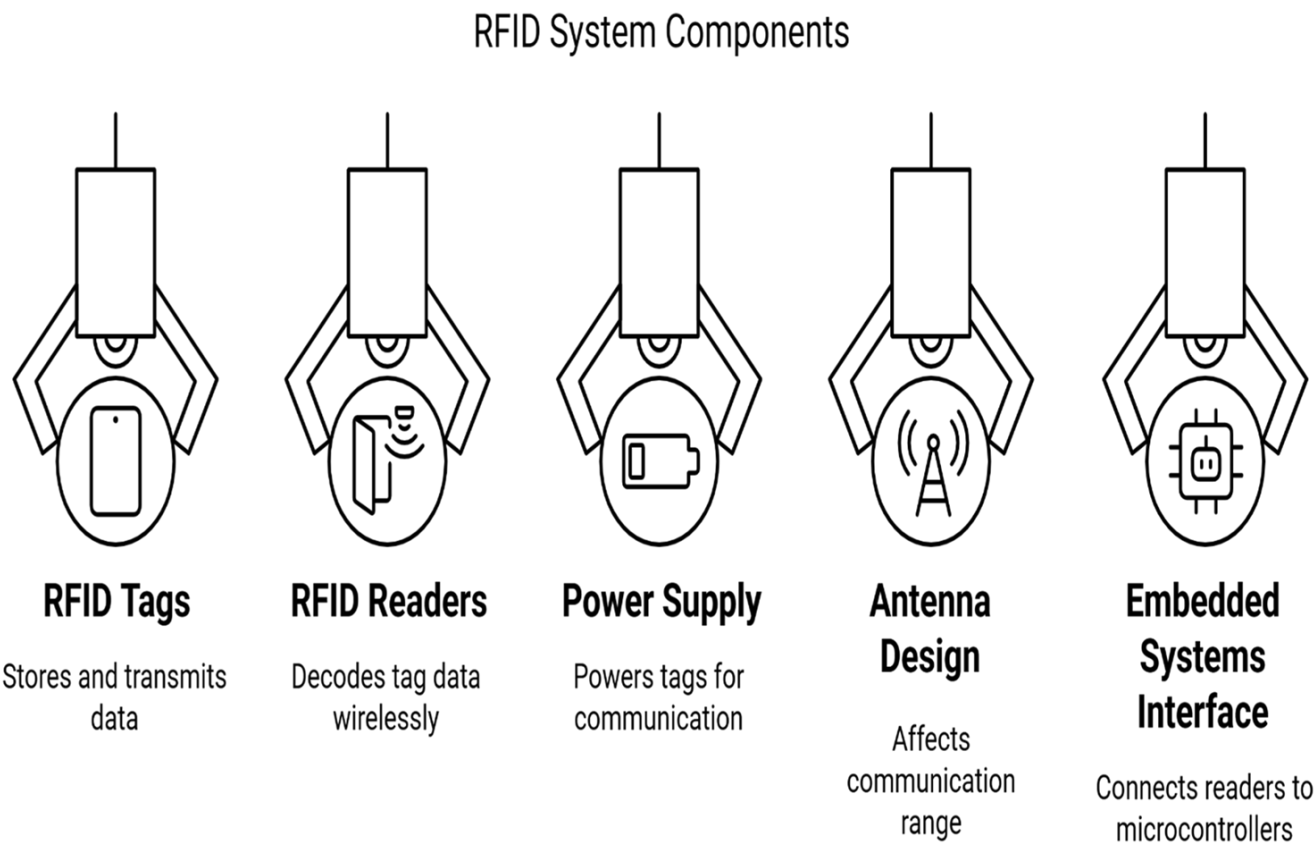
3.5 Interfacing with Embedded Systems

RFID readers connect to microcontrollers (Arduino, Raspberry Pi) via:

✓ UART (Serial)

✓ SPI/I2C

✓ USB/Bluetooth



4. System Architecture & Data Flow

4.1 RFID Tag-Reader Communication Flow

1. Reader sends a signal → Tag responds with its ID.
2. Reader decodes the signal → Sends data to a computer.

4.2 Reader-to-Host Communication

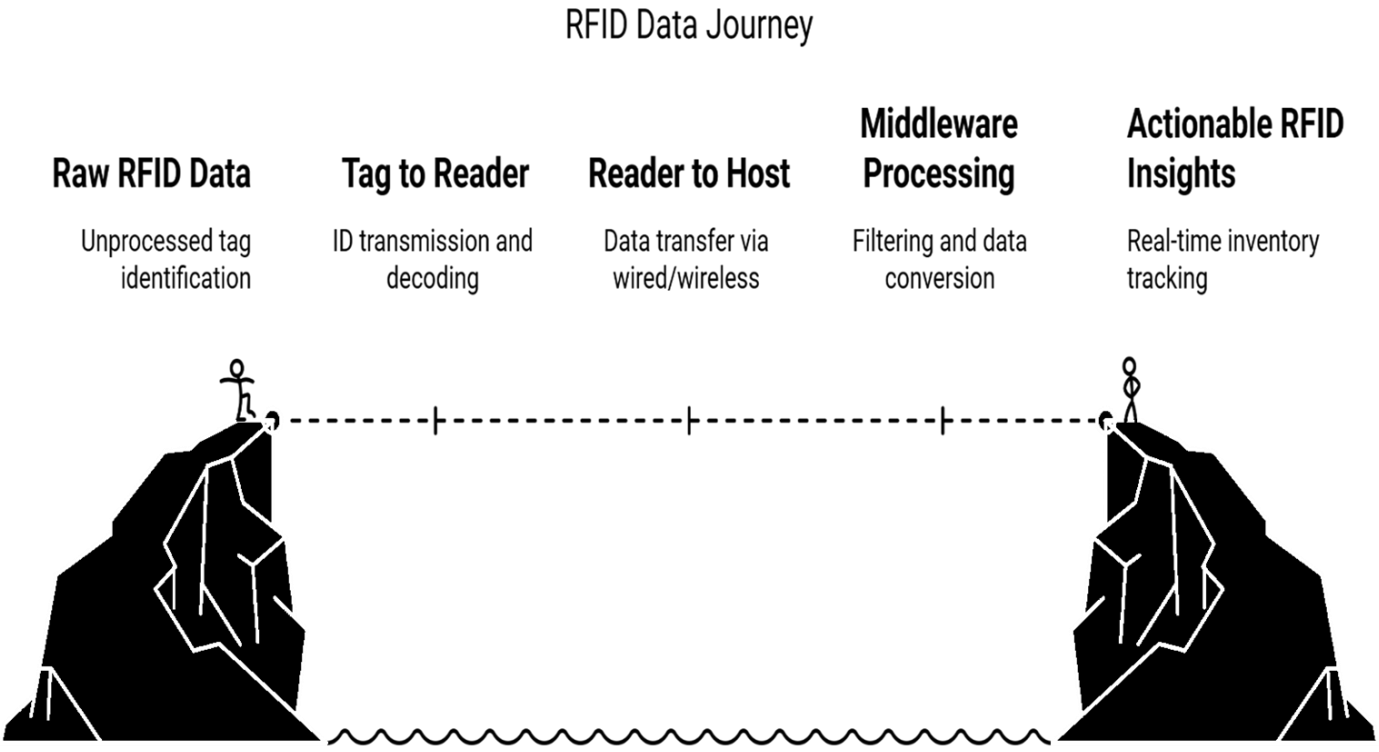
- **Wired (USB, RS232)** – Reliable for fixed systems.
- **Wireless (Wi-Fi, Bluetooth)** – Flexible for mobile setups.

4.3 Integration with Cloud/IoT

✓ RFID data → Cloud server → Mobile alerts / Analytics.
✓ Example: Amazon warehouse tracks inventory in real-time.

4.4 Middleware Functions

- Filters duplicate reads.
- Converts raw data into useful info (e.g., "Product X is in Aisle 3").



5. Embedded Software Lifecycle

5.1 Firmware for RFID Readers

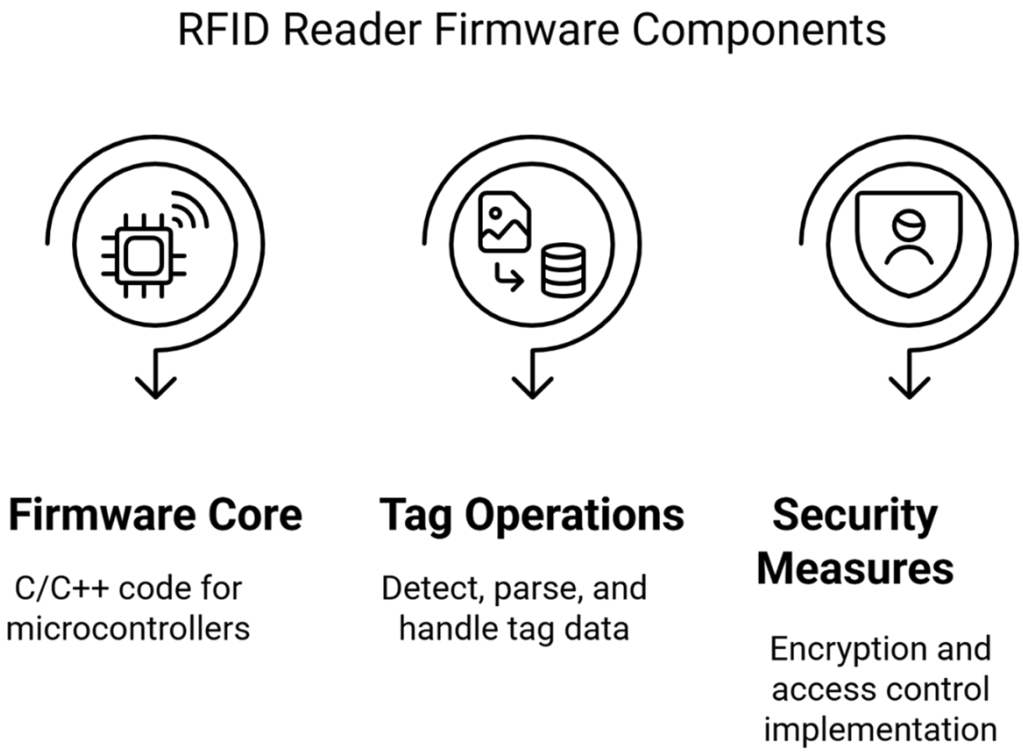
- Written in **C/C++** for microcontrollers.
- Handles **tag detection, anti-collision, data parsing.**

5.2 Tag Data Handling

- **EPC (Electronic Product Code)** – Standard RFID identifier.
- **Encoding Logic** – Writing data to tags (e.g., product details).

5.3 Security & Privacy

- **Encryption** (e.g., AES) to prevent cloning.
- **Access Control** – Only authorized readers can scan tags.



6. Pseudocode & Logic Examples

6.1 RFID Tag Detection Logic

```
reader = RFID_Reader()
while True:
    tag_id = reader.scan()
    if tag_id:
        print("Detected Tag:", tag_id)
```

6.4 RFID-Based Attendance System

1. Employee taps RFID card.
2. System logs time + ID → sends to database.

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7. Design Challenges & Solutions

Challenge	Solution
Tag Collision	Anti-collision protocols (e.g., Q-Algorithm)
Signal Interference	Use different frequency bands
Security Risks	Encrypted tags, secure authentication

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8. Future Trends

- **RFID + IoT** – Smart shelves in retail.
- **Blockchain + RFID** – Secure supply chain tracking.
- **Battery-free Sensors** – Self-powered RFID tags.

9. References

1. IEEE Research Papers on RFID Advancements

- ∞ https://2025.ieee-rfid-ta.org/specialissue
- ∞ https://www.rfidjournal.com/

2. NXP RFID Datasheets & Resources

HF/NFC Solutions:

- **MIFARE®** (e.g., DESFire, Classic) for smart cities and access control .
- **NTAG®** for connected NFC tags (e.g., smart packaging) .
- ∞ https://www.nxp.com/products/rfid-nfc:RFID-NFC

UHF (RAIN RFID) Solutions:

- **UCODE® 9xm**: High-memory tags for industrial IoT .
- **UCODE DNA**: Cryptographic authentication for anti-counterfeiting
- ∞ https://www.nxp.com/products/rfid-nfc/ucode-rain-rfid-uhf:MC_50483