An Introduction to Passive RFID

A ZEBRA WHITE PAPER

Throughout the manufacturing, logistics, and perishable food industries, radio frequency identification (RFID) technologies enable asset tracking, streamline the supply chain, and help improve operational efficiency. RFID is an automatic identification technology that relies on radio frequency (RF) waves to read encoded digital data. RFID is similar to bar code technology in concept. However, reading a bar code requires a line of sight optical scan. RFID does not require a visible tag or label to read its stored data—a powerful benefit unmatched by any other technology today.

The discussion that follows provides an overview of RFID technology, describes current standards, and details how RFID can complement existing bar code technology while enabling new applications in diverse industries.

Passive RFID—The Basics

Passive RFID Tags

Passive RFID tags contain a low-power integrated circuit (IC) attached to an antenna, and are enclosed with protective packaging (like a plastic card) as determined by the application. On-board memory within the IC stores data. The IC then transmits/receives information through the antenna to an external reader, called an interrogator. High-frequency (HF) tags use antennas made of a small coil of wires, while ultrahigh-frequency (UHF) tags contain dipole antennas with a matching wire loop.

Depending on the application, users sometimes call tags transponders or inlays. Technically, an inlay is a tag on a flexible substrate that is ready for conversion into a smart label. RFID tags come in many forms and sizes, some as small as 10 x 10 mm.

Passive tags receive all of their power from the external tag reader, allowing the tag to "wake up" and transmit data. Tags also can be read-only (stored data can be read but not changed), read/write (stored data can be altered or rewritten), or a combination in which some data is permanently stored while other memory remains accessible for later encoding and updates.

Another type of tag, a smart label, extends basic RFID functionality by combining human-readable information and bar code technology. A smart label consists of a paper or synthetic adhesive label embedded with an RFID tag inlay. Smart labels combine the read range and unattended processing capability of tags with the convenience and flexibility of on-demand label printing.

Users can pre-print and pre-code smart labels for unique requirements. In on-demand applications, a printer encodes the tag inlay with fixed or variable data. The label can retain all existing formats and layouts needed to support bar codes, text, and graphics for the specific application. Like an RFID tag, smart labels allow reprogramming after initial data encoding. Smart labels typically range from 1 x 1 inch to 4 x 6 inches.

An emerging RFID technology—Battery Assist Passive (BAP) tags—functions like a passive tag, but uses a battery to boost the RF signal, enabling a much longer range. With all the passive RFID options currently available, business and government enterprises gain a wide range of unique capabilities for automatic data capturing including:

- A robust real-time system that enables wireless identification of data, reduces human intervention, and improves operational efficiency.

- Users now have unmatched flexibility to implement systems that do not require line-of-site scanners for operation.
- Significant local storage capacity—standard passive tags contain 96 bit to 1K bits of memory, while specialty tags can contain several kilobytes.
- Allows enterprises to alter stored data during sorting and rapidly capture workflow process information.
- A tracking system that works reliably across a wide range of environments—even in harsh conditions containing excessive dirt, dust, moisture, and extreme temperatures.

Key RFID Attributes

Passive RFID Standards

HF RFID is a first-generation, short-range technology originally commercialized for access control and contactless payment applications. Passive HF tag systems operate at 13.56 MHz, and enable read ranges from a few inches to 3 feet. Today, there are several widely used HF protocols and standards. Those developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission Joint Technical Committee (JTC 1) remain the most widely used.

Building upon the original HF concept while leveraging Electronic Product Code™ technology, the EPCglobal organization developed the UHF Gen 2 standard so users could accurately identify multiple items at distances not possible with HF RFID tags. The ISO ratified UHF Gen 2 as an international standard for use worldwide. Currently, UHF Gen 2 stands as the dominant RFID technology for supply chain applications, and is widely used for industrial automation, asset management, inventory monitoring, personal ID, and access control. For more information, see www.epcglobalinc.org and www.gs1.org.

Table 1: Passive RFID Standards

	UHF	HF	
Protocols	EPC Gen 2 (ISO 18000-6C)	ISO 15693	ISO 14443
Source	Developed by MIT Auto ID center and EPCglobal	Vicinity read, developed by ISO/IEC JTC1	Proximity read, developed by ISO/IEC JTC1
RF Transmission	Propagating Back Scatter	Electromagnetic Inductive Coupling	
Frequency	860-960 MHz (Regionally Dependent)	13.56 MHz (Global)	
Read Ranges	3-5 meters+	1 meter	0.1 meter
Reader Cost	500-$2000	100-$1000	
Tag Cost	~0.10-$0.20	0.20-$0.50	
Memory Storage	96 bits to 1 Kbits	256 bits to 8 Kbytes	
Security	Read/write protection, anti-cloning, and no encryption	Multiple encryption/security features	
Applications	Supply chain, manufacturing, asset tracking, item level tracking	Access control, secure payment, authentication, healthcare	

RFID Read Range Considerations

With HF systems, the size of a tag (and hence area of antenna) significantly impacts read range. In fact, range depends on several factors including RF interference, antenna size, data protocol, and RF output power. HF systems use inductive coupling, which means that the RFID tag and reader communicates strictly through the electromagnetic near field. However, the RF field strength decreases quickly, limiting some HF applications to a read range of between 6 and 8 inches.

UHF Gen 2 systems use RF propagation technology in the 860-960 MHz frequency bands to communicate—providing stable read ranges often greater than 25 feet. For EPC Gen 2 UHF tags, there are many designs from which to choose. UHF reader equipment varies by region and regulatory requirements. In fact, UHF tag performance in terms of readability depends on much more than just tag antenna design. Other areas for consideration include the tag's ability to extract, consume, or reflect an RF signal from an interrogator, how distance or orientation to the interrogator changes a tag's performance, and how nearby materials such as metal or water affect read rates.

How the Environment Affects RFID Performance

When selecting RFID technologies, businesses must determine if applications will operate in extreme conditions (for example, temperature, or humidity). The typical operating temperature for an RFID inlay (tag) within most smart labels is between -13º F/-25º C and 158º F/70º C. Storage temperature typically ranges between -40º F/-40º C and 185º F/85º C. Environmental values vary between manufacturers, and depend on the tag's components and packaging materials.

Industrial tags currently are available that can withstand temperatures as high as 482º F/250º C, allowing the tags to withstand heat sterilization requirements for medical items. In medical RFID applications, X-rays do not affect a tag, but this factor depends on the radiation intensity. However, gamma radiation, typically used in medical instrument sterilization processes, can erase or destroy most silicon-based electronic circuits.

Reading and Writing RFID—Diverse Solutions

An RFID reader contains a radio frequency transmitter and receiver controlled by a microprocessor or digital signal processor (DSP). The reader uses an attached antenna to capture data from tags. The reader scans the tag, and then passes the data to a computer (mobile, handheld, or fixed system) for interpretation, storage, and processing. Depending on the application, the reader can also write new data to the tag.

An RFID reader can communicate with a computer through a variety of interfaces (RS232, USB, Ethernet, Bluetooth®, and GPRS). The amount of memory a reader contains for data and event logging varies substantially. Readers come in an array of sizes and options and can be affixed in a stationary position (for example, beside a conveyor belt in a factory or dock doors in a warehouse), portable (integrated into a mobile computer that also might be used for scanning bar codes), or even embedded in electronic equipment such as print-on-demand label printers.

Protecting Critical Data—RFID and Security

When it comes to data protection, there is a trade-off between RFID costs, read range, and security. Adding data encryption not only increases a tag's cost, it also reduces the available storage capacity, and increases the read cycle delay—all key considerations when choosing RFID technologies.

For HF tags, many levels of security exist, from limited security (ISO 15693) to basic encryption and beyond (ISO 14443). ISO 15693 offers no read protection, encryption, or authentication. However, the standard supports optional write protection, air interface error checking, and optional lock password protection. ISO 14443, developed for the banking industry to enable secure payments, supports several types of encryption such as the 128-bit

Advanced Encryption Standard (AES), triple-Data Encryption Standard (DES), and Secure Hash Algorithm (SHA-1) encryption.

UHF Gen 2 RFID systems do not support encryption, and the data remains open and readable by anyone with equipment that complies with the protocol standard. Security provisions in UHF Gen 2 include multiple levels of write data protection, while some tags also offer read protection.

In addition, most UHF Gen 2 devices contain features to guard against tag cloning. Typically, cloning protection exists in the form of a Unique Identifier (UID) permanently encoded to the chip by the manufacturer. Several security features are optional, requiring activation during system setup. Users can encode additional data in the user memory, and apply separate levels of security to each memory block. By using the "permalock" feature, users can lock data into Gen 2 chip memory to prevent data rewrites.

RFID Application Considerations

Choosing RFID or Bar Code—It Depends on the Application

Bar codes and RFID are quite similar since both provide rapid, reliable item identification-and-tracking capabilities. The primary difference is that bar coding scans a printed label with optical laser or imaging technology, while RFID scans a tag using RF. Because of the low cost of labels, established standards, and global deployment, bar coding is a widely accepted, mature technology. Until recently, RFID was limited to niche applications. Furthermore, just as there are different bar code symbologies in use today, there are different RFID standards for RF communication protocols.

Bar codes and RFID technologies are both enabling solutions with different physical attributes; they are not mutually exclusive, nor will one replace the other. Bar codes utilize one-way, serialized, static data. RFID utilizes two-way, parallel, dynamic data.

Forward-thinking companies are using their current bar code systems to benchmark RFID technology in order to gauge impact on performance. This baseline is a crucial measure in determining the effectiveness of a new RFID system. Separating the data aspect of RFID systems from the physical architecture is an optimal way to start to learn the physical properties of RFID. The determination of when to use RFID technologies instead of bar codes depends on whether RFID can improve an existing business process. Because bar codes and RFID are complementary technologies, future processes may still require the use of both technologies—wireless and human readable—to address unique business needs.

Fundamental RFID Applications

Manufacturing and Supply Chain Tracking

Because RFID technology operates 24/7, without constant human intervention and line-of-sight reading required by bar codes, the simple addition of RFID tags to components in a manufacturing process allows laborers to assemble the product, pack the shipping carton, and seal it. Validation occurs automatically throughout the regular production line and after workers seal the product housing.

At the location where the sealed box crosses from packing into the storage area, an RFID reader tied into the manufacturing execution system verifies the box contents against the order. As a result, operators can remove boxes missing the correct components before they enter the finished goods area, and send them for rework. The result is lower costs, greater efficiency, and improved customer service.

Today, businesses extensively use UHF Gen 2 RFID for asset management and product identification applications. In this scenario, unattended dock door readers mounted 10-20 feet away automatically identify and record an entire pallet of goods. For example, the standard UHF specification supports identification of more than 1,000 tags per second.

Asset Tracking

Real-time locating systems based on RFID tags are experiencing widespread use. Given the escalating costs of IT hardware, data centers are looking for ways to track assets. Passive RFID tags are ideally suited for IT asset identification such as tracking of servers, small high-value electronic devices, network cards, and other assets.

Tracking applications deploy RF transceivers (similar to WLAN access points) at key points throughout a facility. Each asset contains a passive UHF Gen 2 tag that contains a unique identification number. The result is a highly automated system that enables real-time inventory and location-based tracking of critical infrastructure, while providing a cost-effective deterrent to theft. RFID wireless range and fast identification capabilities also enable significant benefits to ID applications in both the private and public sector.

Food Traceability

RFID can deliver significant benefits to businesses requiring tight deadlines to deliver goods to shelves during the retail operation, such as the perishable goods industry. Some food products can spoil in as little as seven days. RFID tags are the optimal solution for tracking food products throughout the supply chain. Specialized RFID tags can even record ambient data, such as temperature or humidity to indicate the remaining product shelf life. The benefits of applying RFID to perishable goods include improved food safety, more efficient product recalls, and a reduction in costs due to less spoilage, lower inventories, more efficient logistics, and enhanced customer satisfaction.

Collaboration and Compliance

Major retailers recognize the key benefits that passive RFID brings to inventory management. Since 2005, Wal-Mart began requiring its top 100 suppliers to place EPC-based RFID tags on pallets and cases, with a focus on a collaborative effort that helps suppliers realize the payback. To reduce out-of-stock items, optimize inventory management, and improve order reconciliation, Sam's Club set a mandate of tagging all sellable units by October 31, 2010.

The private sector is not the only enterprise to capitalize on the benefits of RFID. Several years ago, the U.S. Department of Defense (DOD) began a process of removing inefficiencies in its supply chain—the largest and most complex in the world. Through RFID, the armed services gained significant savings in labor and inventory by tracking parts used during combat and support equipment maintenance. Under a DOD compliance mandate, all parts suppliers must attach passive RFID tags to pallets of goods shipped to depots operated by the Defense Logistics Agency (DLA), the DOD's logistics arm. Today, the DLA receives tagged pallets from 4,000 suppliers, and achieves a remarkable 180,000 tag reads per month at its maintenance depots.

Optimizing the Distribution Process

When a business adds simple RFID package validation through remote package scans, this improvement alone can provide a significant return on investment (ROI). Simplifying order fulfillment and validation prevents incorrect orders, thus increasing shipping accuracy. ROI improvements include forward logistic efficiencies and savings in reverse logistics. Specifically, business will realize lower shipping fees for incorrect product shipments, fewer disruptions due to restocking and repackaging, and a reduction in customer service and technical support needs.

RFID Enables a Diverse Variety of Applications

RFID in logistics applications allows readers to scan multiple tags simultaneously. In this scenario, system designers can configure the reader application to understand which tag to read at a specific event—for example, arrival at a dock door. Many RFID tags have the ability to differentiate themselves using application identifiers that alert the system whether they are an item-, case-, or pallet-level tag. In addition, some tag designs work with metal in near proximity—a material that reduces tag scan range. Tags used in metallic applications require a non-metallic "spacer" (for example, air, cardboard, plastic, etc) to function properly.

RFID System-Level Integration

ERP Integration

Numerous system integrators, including those providing enterprise resource planning (ERP) software, deliver management applications for RFID readers, printer/encoders, and tag data capture. For example, the SAP® Auto-ID Infrastructure (AII) enables backend systems like ERP and supply chain tools to take advantage of RFID technology. SAP AII connects the physical world, as observed by RFID readers, with a business-oriented view of ERP systems. As a result, RFID can detect inbound merchandise at the loading dock of a distribution warehouse, and confirm the completed delivery directly to the ERP application.

EDI Integration

Electronic Data Interchange (EDI) messages contain data about business transactions. While the format of an EDI message may change to accommodate new data, fundamentally EDI message processors do not care about the source of the data. However, one area of difference is that many EDI systems typically deliver data in periodic batch mode; in contrast, the strength of RFID is its ability to deliver real-time data. To allow seamless communication between EDI, RFID, and SAP systems, applications exist such as the Microsoft® BizTalk® Server.

RFID Reader Integration

Readers come in a vast array of sizes and options and can be affixed in a stationary position (for example, beside a conveyor belt in a factory or dock doors in a warehouse), portable (integrated into a mobile computer that also might be used for scanning bar codes), or even embedded in electronic equipment such as print-on-demand label printers. Readers range from an elementary device with minimal complexity, designed for embedded applications like those found within a Zebra printer/encoder, to a sophisticated reader used in high-performance situations such as on a high-speed conveyor.

RFID Delivers Essential Benefits

By integrating wireless technology with the power of dynamic data storage, passive RFID technology extends the application space for asset tracking, supply chain management, and access control. The most effective RFID systems take advantage of IT integration technologies to support the organization's unique value proposition and process requirements. With RFID, enterprises gain a flexible tagging solution that complements an existing bar code infrastructure and creates new opportunities for reducing costs and improving operational efficiencies.

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GLOBAL/AMERICAS HEADQUARTERS
Zebra Technologies Corporation
333 Corporate Woods Parkway
Vernon Hills, IL 60061-3109 U.S.A.
T: +1 847 793 2600 or
+1 800 423 0442
F: +1 847 913 8766

EMEA HEADQUARTERS
Zebra Technologies Europe Limited
Dukes Meadow
Millboard Road
Bourne End
Buckinghamshire SL8 5XF, UK
T: +44 (0)1628 556000
F: +44 (0)1628 556001

ASIA-PACIFIC HEADQUARTERS
Zebra Technologies Asia Pacific, LLC
120 Robinson Road
#06-01 Parakou Building
Singapore 068913
T: +65 6858 0722
F: +65 6885 0838

OTHER LOCATIONS
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California, Georgia, Rhode Island, Texas, Wisconsin
EUROPE
France, Germany, Italy, Netherlands, Poland, Spain, Sweden
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