A Zebra Technologies White Paper

Tips for RFID Smart Label Printing/Encoding

Executive Summary

Zebra Technologies introduced the first integrated, on-demand radio frequency identification (RFID) smart label printer/encoder in 2001, and since then we have worked with hundreds of customers around the world who use different RFID protocols, frequencies, inlay designs, and standards. This experience has taught us several best practices that are applicable to any smart label printing operation.

Accurate RFID encoding is critical to every deployment. If the printer/encoder does not perform the tag data and item association correctly, the errors can propagate throughout the entire supply chain. Following the tips described in this white paper can help you get more from your smart label printing system by improving reliability, minimizing operator intervention, reducing wasted labels, preventing encoding and printing errors, and yielding more usable labels per media roll.

RFID Smart Label Overview

Printable RFID tags contain a low-power integrated circuit (IC) attached to an antenna, and enclosed with protective material (label media) 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. Traditional RFID printer/encoders often require an inlay pitch of 50 mm or more to ensure accurate data encoding. Pitch is the distance from the leading edge of an inlay to the leading edge of the next inlay on the printing web. Shipping compliance and immature chip technology originally drove the 50 mm requirement. Most RFID printers available today contain older RF encoding technology designed for legacy applications such as pallet tracking, forcing them to support a minimum inlay pitch of only 50 mm.

Pitch depends on the inlay size, and the smallest inlays today use a 16 mm pitch. Unfortunately, traditional RFID printer/encoders cannot take advantage of these reduced-pitch inlays. As a result, the label converter must add an extra process to space out the inlays prior to encoding or tagging, which adds unnecessary overhead to media costs.

Passive tags receive all of their power from the external tag reader, allowing the tag to "wake up" and transmit data. Quite frequently, manufacturers optimize tags for long-range and robust read rates, with the goal of reading hundreds of tags at once, sometimes several meters away. However, a printer/encoder's task is unique—the goal is to encode one specific tag, in the close vicinity of hundreds or even thousands of other tags—not an easy task.

Fundamentals: How Printers Create Smart Labels

Smart label printer/encoders use media that contains an RFID inlay (chip and aluminum, copper or silver antenna bonded to a polyethylene terephthalate (PET) layer) embedded within the label material. The inlay ships to the label manufacturer without adhesive ("dry"), or attached to a pressure-sensitive liner ("wet").

"Converted label" processes embed the RFID inlay into a self-adhesive paper label. An RFID encoder inside the printer writes pre-determined data to the RFID tag using radio frequency (RF) transmission. Next, the printer prints bar codes, text, and graphics using the standard thermal printing process.

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. UHF Gen 2 is the dominant RFID smart labeling technology for supply chain applications, 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, and now maintained by ISO and GS1	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	10+ meters+	1 meter	0.1 meter
Reader Cost	500-$1500	100-$1000	
Tag Cost	~0.10	0.20-$0.50	
Memory Storage	96 bits to several Kbits	256 bits to 8 Kbytes	
Security	Read/write protection, anti-cloning, and no encryption	Multiple encryption/security features	
Applications	Retail item level, supply chain, asset tracking, access control, authentication	Access control, secure payment, authentication, ticketing	

Selecting the Right Media

Matching media with the printer and application is important to the success of any label printing system, but is critical for RFID smart label printing/encoding. RFID systems are designed to minimize interference, ensure data integrity, and provide maximum read range. RFID read range and data integrity depend on high-quality smart labels. The smart label must reliably transfer data in a dependable, predictable manner, and—in classic domino effect—the success or failure of the RFID system depends on meeting this requirement. Smart label material should adequately protect the inlay and not provide potential interference, which affects range and reliability. Due diligence with regard to smart label selection can make a huge difference on whether an RFID implementation achieves success or not.

Select a Printer That Prints and Encodes On-Pitch

On-pitch RFID printers encode tags at the same pitch as specified by the inlay manufacturer, thus eliminating the extra process of spreading apart the inlays prior to encoding. Successful on-pitch printing requires printers designed with tight mechanical tolerances, advanced RF technology, and intelligent firmware. On-pitch RFID printers must also support easy integration with wireless networking, provide a future-proofed path for upgrades as RFID standards evolve, and offer flexibility to support various inlay types and smart label requirements.

Zebra delivers intelligent RFID printer/encoders that accurately and cost-effectively create smart labels down to 16 mm of pitch. Zebra printers require no mechanical changes, additional RF shielding, or other modifications, allowing fast setup and efficient long-term operations. Embedded firmware automatically drives the printing/encoding process, and provides flexible support for different media label sizes. Zebra RFID printers deliver an average of 10 percent cost savings per tag, which is significant when factoring the scale of product movement in the apparel and other mass-volume retail industries.

Match the Chip Position to the Printer/Encoder

RFID users should perform testing to find the best frequency, protocol, inlay manufacturer, and design for their application's needs. A common mistake is to place a large order for smart labels early on in the testing phase without making sure the media meets optimization requirements for the chosen printer/encoder. In fact, smart label media is often not interoperable among different brands of printer/encoders that support the same RFID protocol. Therefore, the specific media requires calibration to the specific printer/encoder model to ensure proper alignment and encoding.

The latest generation of printer/encoders support variable inlay placement with adaptive array encoding. Printer/encoder specifications list specific inlay manufacturers and label/tag designs that they support. It is critical that the media provider conforms to these specifications when an RFID user designs smart labels to fit an application. In order to verify that the provider followed the specifications, end users should obtain samples or place a small initial order for testing purposes.

Avoid Foil and Metal-based Media

Do not use foil or metal-based label stocks for smart labels. Metal reflects RF signals and is a leading source of RFID interference. Embedding an RFID inlay within a metal or foil label can prevent successful encoding/reading, and severely limits range. Bar code label media sometimes use foil and metal-based media to enhance bar code performance by providing more light reflection. The media provides no such benefit for RFID, which is not an optical technology.

Watch out for Liquids

Liquids are the other leading hindrance to RFID system performance. Liquids can absorb RF signals, which can severely limit range or prevent tag encoding/reading altogether. Therefore, label placement on liquid products is critical in order to achieve successful read rates and distance. In addition, synthetic media and laminates commonly used to protect bar code labels from moisture and liquids pose no problems to smart label performance.

Storage Temperature

Smart label media can withstand a wide range of temperatures, so storage temperature is not usually a concern. Performance will remain optimal if storage temperatures are kept between -60° and +203° F (-51° and +95° C).

Limit Electrostatic Discharge (ESD)

ESD dangers are elevated in low-humidity and high-altitude locations. This may seem like a small consideration, but failing to control for ESD can seriously affect smart label performance and lead to more cost and problems during an RFID implementation. Storing media in non-conductive bags or cartons (cardboard is sufficient) should provide sufficient protection against ESD damage. If ESD is a persistent problem, operators may need to wear anti-static clothing or wear grounding straps like those used in other environments containing sensitive electronic components.

Printer Management

Procedures and training, optional printer/encoder settings and features, and the physical location of the printer/encoder itself all contribute to successful smart labeling. Be sure to give printer/encoders that offer configurable error settings and other flexible options top consideration because they can increase uptime and minimize operator intervention.

Centralize Management Tasks

With the consolidation of operations that is prevalent in most manufacturing and IT organizations, there is a trend toward centralized management and administration of peripheral equipment, including printers. Enterprise-level middleware and printer applications close the gap between label printer-specific support provided by traditional printer utilities and the centralized management, configuration, and control available in general-purpose management applications. Now, users can manage all their networked printers globally from a single desktop application, and "push" changes to printers as needed.

Other printer management options use a "pull" networking task. This capability allows IT administrators to configure and load printer information on a networked server once, then allow the printers to pull the data as needed. Printers can pull settings, objects, and even firmware from a centralized FTP server. Administrators can synchronize the printers with specific files maintained on a server using several scenarios including when the printer powers up, at specified time intervals, both on power up and at time intervals, or on command.

Pick Printer Placement Carefully

Encoding performance can improve simply by allowing some physical space between the printer/encoder and other RF products that share the same bandwidth. Interference may result if the printer/encoder is next to or directly above or below other RF devices. Remember that the printer/encoder itself is a shield to outside RF signals. Removing the printer's housing or enclosure can compromise the printer's resistance to interference, reducing encoding performance.

Maximize Encoding Success

Printer/encoders should perform two tag quality checks. The first check, prior to encoding, verifies that the inlay is functional and can receive data. The second check verifies that data encoded and stored on the chip correctly. Encoding the inlay and printing the smart label should require only a single pass through the printer/encoder. A key consideration in facilitating smooth printing/encoding operations is to ensure that the label edge properly aligns so that the tag is in proper programmable position for encoding. Avoid the practice of manually aligning labels, which is common in bar coding. Precise positioning is required to enable the tag for encoding. The best practice is to adjust label location through printer/encoder commands or through label-design software.

For example, Zebra Programming Language (ZPL®) includes the "Label Home" script usable for adjusting the label's top position. Label design software packages also have features to adjust label layout. Some printer/encoders have programmable encoding positions that allow setting the encoding location from the control panel or through the printer command language. Printer/encoders with a self-calibration feature—again an optimal choice—can automatically determine the best encoding position. The latest printer/encoder technology supports an RFID calibration feature with automatic program position selection for optimal transponder placement.

Limit Error Messages

Inlays fail to encode for a variety of reasons. It is common for inlays not to encode on the first try, so failure to do so does not necessarily indicate a problem. Therefore, it is not practical to issue an error message or shut down the printer/encoder each time there is a failure to encode. Printers can be set to automatically retry encoding. When considering the purchase of a smart label printer/encoder, choose one that allows you to adjust the number of encoding retries to program the smart label before sending an error message. This flexibility will ensure the highest percentage of yield rates from your media.

Designate and Segregate Unencoded Labels

Sometimes rolls of smart label media suffer damage and portions of the roll will fail to encode. Processes need to be in place to prevent users from applying damaged or unprogrammable smart labels to items. Unusable labels should be clearly marked with a printed "VOID" message. Another option is to stop the printing process when an unencoded label occurs. This prevents further printing until the error is resolved—an action only recommended in the case of persistent problems.

Use Alerts for Persistent Problems

Halting operations should be the last step in an escalated response system. There are other options short of time-consuming system shutdowns. Most encoding failures are isolated incidents resulting from a damaged inlay. Consistent failures could indicate a larger problem. Users should program the printer/encoder to issue an alert when a persistent problem arises. Zebra strongly recommends that end users integrate a robust printer and print-server management application in their overall RFID architectures. Software-based monitoring and management of RFID printer/encoders can provide alerts and capture statistics on printer/encoder performance to flag problems before they have serious consequences.

Achieving Proper Label Placement

Many of the best practices of successful smart label printing and encoding apply to placing the label on cases and pallets:

- Proximity to metal and liquid should be avoided
- Care should be given to protect the label against excessive contact
- Consideration should be given to how cases are stacked on pallets to maintain sufficient distance between smart labels
- Conduct testing to determine the optimum smart label placement from the bottom of the pallet. For shrink-wrapped pallets, place smart labels on the outside of the wrap. Bands used to hold pallets or wrappers in place should not wrap around the labels.

Many variables determine the best approach to placing labels on packages, cases, and pallets. A comprehensive guide outlining many of these considerations are detailed in a document created by AIM Global's RFID Expert Group, titled "Proposed Guidelines for the Use of RFID-Enabled Labels in Military Logistics: Recommendations for Revision of MIL-STD-129." Although designed primarily for military logistics, these guidelines have been coordinated with commercial logistics RFID practice so that conveyable goods used in military and civilian approaches can conform to a common standard as far as possible. Request this document from AIM Global.

Conclusion

Businesses across the world print and encode millions of smart labels every year. Most problems that do arise occur because of a few common conditions that are easily resolved. Many problems can be avoided entirely by training associates on the leading causes of smart label failure, such as due diligence in selecting proper media, media handling, and replacing manual printer calibration with auto-calibration models.

Action taken before deploying the system can also save errors and downtime. Care taken early on to optimize media with the specific printer/encoder will save valuable time and costs while improving long-term yields and throughput. Selecting an intelligent, programmable printer/encoder helps optimize operations because the organization can set the unit to support desired processes for error resolution and alert notification. Printer/encoders that offer programmable encoding positions and imaging adjustments make it easier to maintain calibration and uptime.

Many other usage, environmental, and product factors can affect smart label printing/encoding performance. Contact Zebra Technologies to learn more about setting up an efficient smart labeling system for your organization. As a member of EPCglobal, and a technology sponsor of the former Auto-ID Center at MIT, Zebra plays a leading role in the development of smart label technology, standards, and applications for supply chain and business improvement programs. Zebra has provided solutions to many RFID early adopters, including suppliers in the Walmart and U.S. Department of Defense (DoD) compliance programs.

Zebra Technologies Corporation (NASDAQ: ZBRA) provides the broadest range of innovative technology solutions to identify, track, manage, and optimize the deployment of critical assets for improved business efficiency. Zebra's core technologies include reliable on-demand printer and state-of-the-art software and hardware solutions. By enabling improvements in sourcing, visibility, security and accuracy, Zebra helps its customers to put the right asset in the right place at the right time. Zebra operates in over 100 countries and serves more than 90 percent of Fortune 500 companies worldwide. For more information about Zebra's solutions visit www.zebra.com.

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