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White Paper

FROM BAR CODES TO SMART LABELS

How smart labels combine RFID with bar coding for case/pallet pilot applications, and how printer/encoders are the engine for getting started

Smart labels are shipping labels with embedded RFID tags. They offer promise in helping organizations deploy RFID for compliance with retail industry and DoD mandates. Smart labels allow you to retain bar code/shipping label information in the same or similar format to what you are currently using, while adding RFID.

Smart labels provide a convenient and economical way to package RFID tags and stream them into the distribution process. They provide a richer data set than either a tag or barcode by themselves. They provide resiliency, by combining bar code and human-readable text together with electronic data, should one method of identification fail. They comply with consumer and industry guidelines for having a visible indication that a package has an RFID tag. They can be produced on-demand, or pre-printed and pre-coded for batch processing. Labels also provide added protection to the tag from heat, dust and humidity.

Smart labels may be the easiest, least disruptive, least cost way to implement RFID in your facility. They are not only appropriate for case and pallet supply chain applications, they may also be used in a number of applications "within the 4 walls," including receiving, routing, stocking, work-in-process, HAZMAT and asset handling.

If you are already producing bar code labels, a migration to smart labels could involve the integration and re-use of an established process, where:

- On-demand printing and application flexibility is maintained
- Labeling is done at appropriate points in the packaging/shipping process
- RFID integration fits within the small footprint of a smart label printer
- Both automated and operator-assisted application methods are available
- Tag encoding is done predictably and reliably, without custom engineering
- Validation and error recovery is built into the system
- Encoding and printing commands share an established host computer to shop floor network
- System migration and integration can be simplified using conversion tools and software modules from multiple middleware and supply chain execution system suppliers, so you don't have to rewrite applications.

ANATOMY OF A SMART LABEL

Figure 1 provides two views of a smart label. The surface area is used for standard bar code and label text. The RFID tag is sandwiched in the middle. The label sandwich consists of six parts — the liner or carrier sheet, the liner release coating, the tag inlay, an adhesive, the label material and a label topcoat.

Labels are printed using a thermal print process. A print head, embedded with a matrix of tiny heat elements that are precisely controlled, uses heat to transfer a wax or resin ink to the label. The ink is on a separate ribbon inside the printer. Smart labels come in rolls of various sizes which, along with the ribbon roll, are mounted inside the printer/encoder. An alternative to the label/ribbon system is direct thermal media, whereby chemicals in the label turn black when headed by the print head.

Figure 1 – Two views of a smart label.

SELECTING THE RIGHT SMART LABEL FOR THE JOB

Smart labels are available in bulk roll quantities in a variety and sizes and types. You'll find formats that allow smart labels to substitute for existing bar code labels designed to meet corporate and supply chain standards (mil spec labels, freezer grade labels, pharmaceutical chain of custody labels, etc.). Three basic criteria should drive selection of the right label:

Labeling requirement – The information on the surface of the label and embedded in the tag needs to identify the package contents and its status in the supply chain. Supply chain status could include originator, shipper, ship to and any special handling requirements. Figure 2 shows a typical label format, with address areas and machine readable codes. The amount of information on the front of this label exceeds what is stored in EPC format on the RFID tag.

Figure 2 – Typical format for case labeling.

Application requirement – Tag readability is a major factor. A complete product packaging study (also called a case analysis) is required to ensure tag readability. Case analysis should include a comprehensive assessment of package contents, packaging design, label placement and the package labeling process. Package contents and packaging design may affect tag readability, particularly if metals, liquids, high carbon or salt content is involved. This affects label placement on the package, and package orientation with respect to readers as it moves through the process. Storage and handling requirements determine whether you need such things as freezer-grade adhesive, or polyester rather than paper label material to withstand heat.

Customer requirement — Customer specifications may dictate everything from the volume needed, to the size of label used, the information printed on label surface, location of the label on a package, the EPC information in the tag, the tag/reader air protocol, and acceptance criteria. Acceptance criteria may include such things as read rate (100%), advanced shipping notice (ASN) integration, validations, record keeping and problem handling (charge-backs). The stringency of your customer's acceptance criteria will greatly affect the design criticality of your process. As your labeling process moves into production, the number of labels needed and line speed or throughput will dictate the level of investment needed to meet a customer requirement.

Clearly, putting an RFID tag or smart label on a product is not as easy as applying a bar code label. The engineering trial and error involved is one of the biggest challenges facing companies who have to meet a RFID compliance mandate. Application requirements, as defined by a case analysis, usually determine the choice of smart label. Case analysis will match the application to a specific tag and antenna design. Tag and label manufacturers are greatly expanding their offerings and designs to meet various application requirements.

RIGHT LABEL CERTIFICATION

Although smart labels are available from a number of sources, certain labels may be incompatible with certain printer/encoders. The process of inserting RFID tag inlays into labels is new for many label converter companies. They have encountered many challenges, particularly ESD management, inlay placement accuracy and inlay testing.

Reasons for incompatibility include:

- System migration and integration can be simplified using conversion tools and software modules from multiple middleware and supply chain execution system suppliers, so you don't have to rewrite applications.
- Tag type not matched to the encoder (tags are categorized as class 0, 0+ or 1 and have incompatibilities. The generation 2 standard may eventually resolve them.)
- Tag not at a position within the label so that it is correctly oriented to the printer/encoder antenna
- Label surface material not suitable for high quality production thermal printing
- Adhesive not matched to the package surface to which it will be applied
- Labels (paper versus synthetic) mismatched to the ribbon stock (wax versus resin)

High speed package labeling requires a high quality label. Labels that are difficult to peel, or inconsistently peel from their backing because of poor die cuts will fail and require operator intervention. Poor adhesive application during the label converting process can result in labels lifting as they travel through a printer, causing a jam. The core diameter of label rolls need to be matched to label sizes to reduce the amount of induced curl on labels as the roll unwinds to its core. Curl or adhesion problems will affect how well the vacuum system on an applicator can hold a label in place. Label carrier sheet stiffness can also contribute to applicator problems by making it difficult for the label to separate as it passes through the peel bar.

Certified labels have been pre-tested to eliminate incompatibility, and ensure optimum performance. Label certification is especially important with RFID, since the programming of the tag and synchronization of tag data with printed label data occurs at the printer, all within a second's time. A one percent error rate on labels, for example, when production throughput is 40 labels/minute, would result in almost 200 rejects a day.

ENCODING, PRINTING AND VALADATING SMART LABELS

Initially, passive UHF tags have no data in them. They require an encoding step to load data into them. Encoding can be done by a reader built into an RFID printer, or any reader that is set up for the task. Note that the word "reader" is a general term for a device that can both write to (encode) and read from RFID tags. A smart label printer makes an ideal platform for the tag encoding task for a number of reasons:

Isolation — When reading tags, the reader starts by compiling a list of tags, which it can poll individually if it wants. When writing data to a tag, a reader has to address a tag individually. Isolating the right tag from others around it is very important, to prevent programming the wrong tag. Blank tags won't respond to a call. Some tags have null data in them, inserted by the tag manufacturer during parametric testing. A reader calling to those tags may get the same response from all of them. The only way to synchronize the reader with a blank or null-data tag is by uniquely positioning the tag within a precise read window. That way, the reader has a tag, one tag only, and the right tag within its grasp. A printer/encoder performs this task within a controlled environment.

Proximity — Within approximately one wavelength (l/2p) from a power transmission source, conductive materials experience the affects of near-field electromagnetism. Within the near-field, magnetic coupling occurs. Power flows in the direction of the magnetic field. Near-field energy transfer is more like that of an electric motor, or a power transformer. At greater than one wavelength, radio waves separate and propagate away, no longer aligned with the magnetic field. Energy drops off by the square of the distance. At 900 MHz, the near-field breaks down within a few inches of the source, therefore a reader antenna more than a foot away from a tag cannot take advantage of near-field magnetic coupling. Within a printer/encoder, the tag to encoder antenna position is optimized for near-field energy transfer.

Power and duration — Compared to a read command, a write command requires a higher power level and longer duration. The tag must be able to draw sufficient power from the reader to drive the programming circuitry in the tag. The tag must be within the proximity of the reader for the entire time it takes to program it. A printer/encoder provides this.

You can see that the challenge isn't so much how as it is which tag to program. In the case of an RFID printer, tags are encapsulated in a roll of smart labels, and are a known distance apart from one another. Tag isolation is achieved by the design, positioning and tuning of the reader antenna within the printer chassis. The close proximity of the antenna to the tag is used to advantage, by utilizing the properties of near-field electromagnetism to inductively couple the tag. Because of the encoding time needed, label production time is somewhat less than it takes to produce a bar code label only. The time trade-off, however, is more than compensated for by precise process control, high duty cycles, and validation and error recovery routines that eliminate bad tags and labels being applied to a package.

SMART LABELS COMPARED TO OTHER APPROACHES

Let's look at the pros and cons of other approaches:

Tags integrated with packaging — Disposable corrugated packaging with built-in RFID has several attractive characteristics, most notably that it eliminates tag handling during packing and sealing. Encoding can occur before or after packing.

Tag acquisition and integration costs are pushed down to your suppliers. Disadvantages may include cost and the implications of managing both RFID and non-RFID packaging. Other drawbacks include a lack of clear marking for RF, lack of a backup identification of what has been programmed into the tag, and a huge potential for rework costs because once the box is built, tag location can't be changed. Industry analysts predict that it will take 3 or 4 years for packaging companies to overcome the physical hurdles and make available a comprehensive offering. Error recovery, rework, and charge-backs may actually drive up costs.

Pallets and totes with permanent RFID tags – Such pallets offer a simple approach to pallet level identification, especially where the tags are programmable, and the pallets are dedicated to a specific route in the supply chain. Similarly, for direct-to-store shipments, totes with fixed tags may gain acceptability. This approach might suit the tagging of work-in-process goods during manufacturing as well. Disadvantages when compared to smart labels include the difficulty in encoding unique EPCs with each use, and re-purposing totes and pallet loads. The expected extended life of such tags require ruggedized packaging.

RFID tags only – Another possible approach is applying adhesive backed inlays directly to cases and then programming them when they travel through the packaging line. They might be used in conjunction with an existing shipping label. Although tag-only application may appear to be a less-costly, simpler method, there are a number of drawbacks. Tag inlays, by themselves, are currently not available with the broad selection of adhesives that exists today for labels. RFID tags by themselves do not provide the human readable and bar code backup that smart labels provide. They are subject to the same issues of adhesion to moist, frozen or non-flat surfaces as smart tags, but without being as obvious when they fall off. Consumer privacy groups have also requested a clear indication when an RFID tag is present, which a smart label provides. In addition, smart label printers have validation/recovery routines that prevent a bad tag from ever being applied to a case. Applying just the tag, then programming it while it's moving down the packaging line, necessities package-level rework should the tag fail to read.

The table summarizes the advantages and disadvantages of various approaches compared to smart labels. The observations made here are in the context of pilot applications and initial deployments with the retail industry (Wal-Mart et al) and Department of Defense mandates over the 2 years. In the future we can expect to see a variety of approaches to integrating RFID with today's high-speed retail packaging environments.

Table: Comparison of various tagging approaches to smart labels.

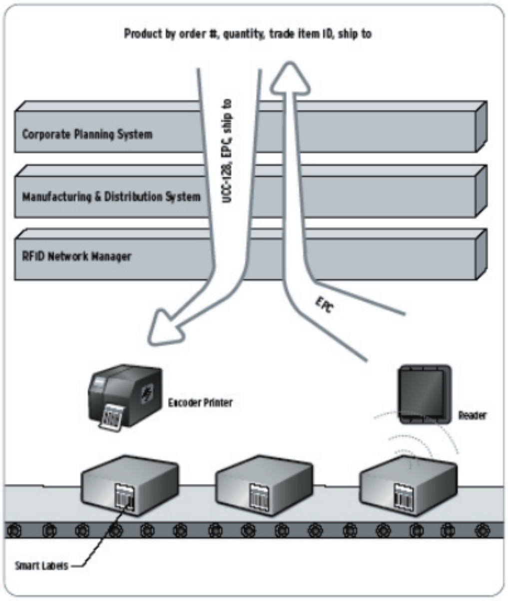
Attribute	Boxes with built-in tags	Pallets/totes with permanent tags	Tags directly applied to cases	Smart labels
Tag location	Fixed and pre-engineered	Fixed and pre-engineered	Flexible	Flexible
Tag application	Built-in prior to packaging	Built-in prior to packaging	Applicator on packaging line	By hand or by applicator
Encoding sequence	Programmed on packaging line	Programmed at shipping dock	Applied then programmed	Programmed then applied
Error recovery sequence	Case unpack & repack	Pallet unpack and repack	Rework	Detection & recovery before applied to case

IMPLEMENTING SMART LABELS

Smart labels can play a key role in an RFID migration strategy. An externally applied adhesive smart label is the easiest, quickest, most flexible way to go from "no tag" to "tag selectively," paving the way to "tag everything." They bridge laboratory and pilot applications by putting tags into play in various environments, so that tag placement, tag orientation, read range, read rates, reader placement, and data management issues can be identified and resolved. In most cases they provide a production or near production line solution at least cost. In all cases they offer a backup reading capability to aid troubleshooting and recovery.

Smart labels are a ready-fit format for most RFID implementations. EPC data flows down to them through a host computer system and printer/encoder. See Figure 3. Labels are applied to parts, products, packages and pallets, uniquely identifying them. Smart-labeled objects are now linked up by radio frequency to a supply chain execution system.

Figure 3 – Operational data flow.



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