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RFID Technology White Paper

1. Radio Frequency Identification (RFID) Overview

1.1. Introduction

This document describes the summary of the Radio Frequency Identification (RFID) technology, its applications, and the IBS HONGKONG’s RFID chip specification.

RFID is a technology that enables the electronic labeling and wireless identification of objects using radio frequency communications. An RFID transponder will identify itself when it detects a signal from a compatible device, known as a reader or interrogator. In a typical RFID system, transponders, or tags, are attached to objects. Each tag carries with it information: a serial number, model number, color, place of assembly or any other imaginable data. When these tags pass through a field generated by a compatible reader, they transmit this information back to the reader, thereby identifying the object.

1.2. Components of an RFID System

A basic RFID system consists of these components:

- A programmable RFID tag/inlay for storing item data;

a. o Consisting of an RFID chip for data storage

b. o And an antenna to facilitate communication with the RFID chip

- A reader/antenna system to interrogate the RFID inlay

- Application software and a host computer system

1.3. RFID Tag

The RFID tag consists of an integrated circuit (IC) embedded in a thin film medium. Information stored in the memory of the RFID chip is transmitted by the antenna circuit embedded in the RFID inlay via radio frequencies, to an RFID reader. The performance characteristics of the RFID tag will then be determined by factors such as the type of IC used, the read/write capability, the radio frequency, power settings, environment, etc.

RFID tags are categorized as either **passive** or **active** depending on whether they have an on-board power source or not.

- **Passive** tags do not have an integrated power source and are powered from the signal carried by the RFID reader. Generally, these tags are powered by the reader antenna through an antenna located on the tag. The reader's transmission is coupled to the specially designed antenna through induction or E-field capacitance which generates a small voltage potential. This power is then used by the IC to transmit a signal back to the reader or reflect back a modulated, encoded identification.

- **Semi-passive** tags have an on-board power source, such as a battery, which is used to run the microchip’s circuitry. However these tags utilize a battery but still operate using backscatter techniques. Tags of this type have greater range than totally passive tags and have the ability to monitor sensor inputs even when they are not in the presence of an RF field.

- **Active** tags incorporate a battery to transmit a signal to a reader antenna. These tags either emit a signal at a predefined interval or transmit only when addressed by a reader. Either way, the battery provides the power for RF transmissions, not an inductive or capacitive coupling. As a result of the built-in battery, active tags can operate at a greater distance and at higher data rates, in return for limited life, driven by the longevity of the built in battery, and higher costs. For a lower cost of implementation, passive tags are a more attractive solution.

The information stored in an RFID chip is defined by its read/write characteristics.

- **Read-only**: For read-only tag**,** the information stored must be recorded during the manufacturing process and cannot be typically modified or erased. The data stored normally represents a unique serial number, which is used as a reference to lookup more details about a particular item in a host system database. Read-only tags are therefore useful for identifying an object, much like the “license plate” of a car.

- **Write-once**: These differ from read-only tags in that they allow the end-user to program the tag’s memory. Therefore, as an item progresses down a conveyor, for example, an end-user can encode a write-once tag with the item's serial number or part number which cannot be erased.

- **Read-write**: for a read/write tag, data can be written and erased on demand at the point of application. Since a rewriteable tag can be updated numerous times, its reusability can help to reduce the number of tags that need to be purchased, and add greater flexibility and intelligence to the application. Additionally, data can be added as the item moves through the supply chain, providing better traceability and updated information. Advanced features also include locking, encryption and disabling the RFID tag.

A barcode scanner cannot read more than one barcode at a time. RFID readers, however, may be driven by specific software applications that can handle the reading of multiple RFID tags. This feature is called **anticollision** as it permits a reader to avoid data collision from several tags that enter the reader’s coverage.

RFID systems are designed to operate at a number of designated frequencies, depending on the application requirements and local radio-frequency regulations:

a. o Low Frequency (125 kHz);

b. o High Frequency (13.56MHz);

c. o Ultra High Frequency (860-960 MHz)

d. o Microwave (2.45 GHz)

Low-frequency tags are typically used for access control & security, manufacturing processes, harsh environments, and animal identification applications in a variety of industries, which require short read ranges. Read ranges are inches to several feet. High-frequency tags were developed as a low cost, small profile alternative to low frequency RFID tags, with the ability to be printed or embedded in substrates such as paper. Popular applications include: library tracking and identification, healthcare patient identification, access control, etc. These tags have a read range of up to several feet. UHF tags boast greater read distances, superior anti-collision capabilities increasing the ability to identify a larger number of tags in the field at a given time. The primary application envisioned for UHF tags, is supply chain tracking. Microwave tags are mostly used in active RFID systems. Offering long range and high data transfer speeds, at significantly higher cost per tag, making them more suitable for railroad car tracking, container tracking, and automated toll collection. Table1 highlights the different characteristics of the four RFID operating frequency ranges.

Table 1: Transponder Performance at Various Transponder Frequencies

Frequency Range	LF 125 KHz	HF 13.56 MHz	UHF 868 - 915 MHz	Microwave 2.45 GHz & 5.8 GHz
Typical Max Read Range (Passive Tags)	< 0.5 m	~ 1 m	~ 3 m	~ 1 m
General Characteristics	Relatively expensive, even at high volumes. Low frequency requires a longer, more expensive copper antenna. Additionally, inductive tags are more expensive than a capacitive tag. Least susceptible to performance degradations from metal and liquids, though read range is very short.	Less expensive than inductive LF tags. Relatively short read range and slower data rates when compared to higher frequencies. Best suited for applications that do not require long range reading of multiple tags.	In large volumes, UHF tags have the potential for being cheaper than LF and HF tags due to recent advances in IC design. Offers good balance between range and performance especially for reading multiple tags.	Similar characteristics to the UHF tag, but with faster read rates. A drawback to this band is that microwave transmissions are most susceptible to performance degradations due to metal and liquids, among other materials. Offers the most directional signal, ideal for certain applications.
			Active tags with	Active tags with

Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitive coupling	integral battery or passive tags using capacitive, E-field coupling	integral battery or passive tags using capacitive, E-field coupling
Typical Applications Today	Access control, animal tracking, vehicle immobilizers, POS applications including SpeedPass	"Smart Cards", Item-level tracking including baggage handling (non-US), libraries	Pallet tracking, electronic toll collection, baggage handling (US)	SCM, electronic toll collection
Notes	Largest install base due to the mature nature of low frequency, inductive transponders.	Currently the most widely available high frequency worldwide, due mainly to the relatively wide adoption of smart cards.	Japan does not allow transmissions in this band. Europe allows 868 MHz whereas the US permits operation at 915 MHz, but at higher power levels.	
Data Rate	Slower			Faster
Ability to read near metal or wet surfaces	Better			Worse
Passive Tag Size	Larger			Smaller

Source: Allied Business Intelligence Inc

1.4. RFID Tag Architectures

Selecting a suitable architecture for RFID tag is dependent on many parameters e.g. required range, data rate, type of application, environment of usage, power availability however low cost, low power and small form factor and low off-chip components are among the most important features that gain more advantage for every category of application. Selecting passive, active or semi-passive is based on the above parameters. At the first glance it seems that active architecture may be of high importance due to high bit rate and read range however through a logical process to mention the fallacies of the standard methods and proposing some solutions to remedy them, we surmise that a hybrid (active -passive chain) with semi-passive (backscattering nature) seems to be a plausible architecture of choice.

Passive tags are smaller, lighter, and less expensive than active tags. Furthermore, passive tags have a virtually unlimited lifetime. Some disadvantages of passive tags are that they have a shorter read range than active tags, and require a much higher-powered reader. Semi-passive tags have greater range than totally passive tags and smaller range than active tags. Since they are not transmitters they require very little power to operate. A typical semi-passive tag using a small watch battery can operate on the order of five to ten years. An active RFID tag uses a battery to run the microchip's circuitry and to broadcast a signal to a reader (the way a cell phone transmits signals to a base station). The advantage of active tags is that they reduce the power requirements of the reader, and they can transmit their information over relatively far distances. The disadvantages are that they have a limited operating life, can only be used in certain environments, and are more expensive than passive devices. The comparison of different architecture for RFID is shown in Table 2.

Figure 2 shows the range limitations for different types of RFID tag. As illustrated in this figure, for passive RFID tag, the range is limited to the achieved (extracted) voltage level by RFID chip. For semi-passive tag, the read range is limited to the sensitivity of the reader and the power of backscattered RF signal at reader's antenna. Also, for active RFID tags, the received signal at the reader's and tag's receiver limits the reading range.

Table 2: Comparison of different RFID architectures

Passive	Semi-passive	Active
+ Smallest and lightest + Unlimited lifetime (not need a battery) + Lowest cost – Shortest read range (usually less than 1 meter) – Require much higher power reader	+ More lifetime than active tag (less power consumption) + Longer read range than passive tags + Less expensive than active tags (no need to crystal and some external parts) – Limited lifetime – Shorter read range than active tag (less than 10 meters) – Require much higher power reader than active tag – More expensive than passive	+ Longer read range than passive and semi-passive tags (usually more than 10 meter) + Require lower power reader than passive and semi-passive tag – Limited lifetime (need to battery) – Shorter lifetime than semi-passive tag (consumes battery power to send data) – More expensive than passive and semi-passive tags (need a battery, crystal and some external parts)

Battery

Figure 1: Semi-passive backscatter RFID system

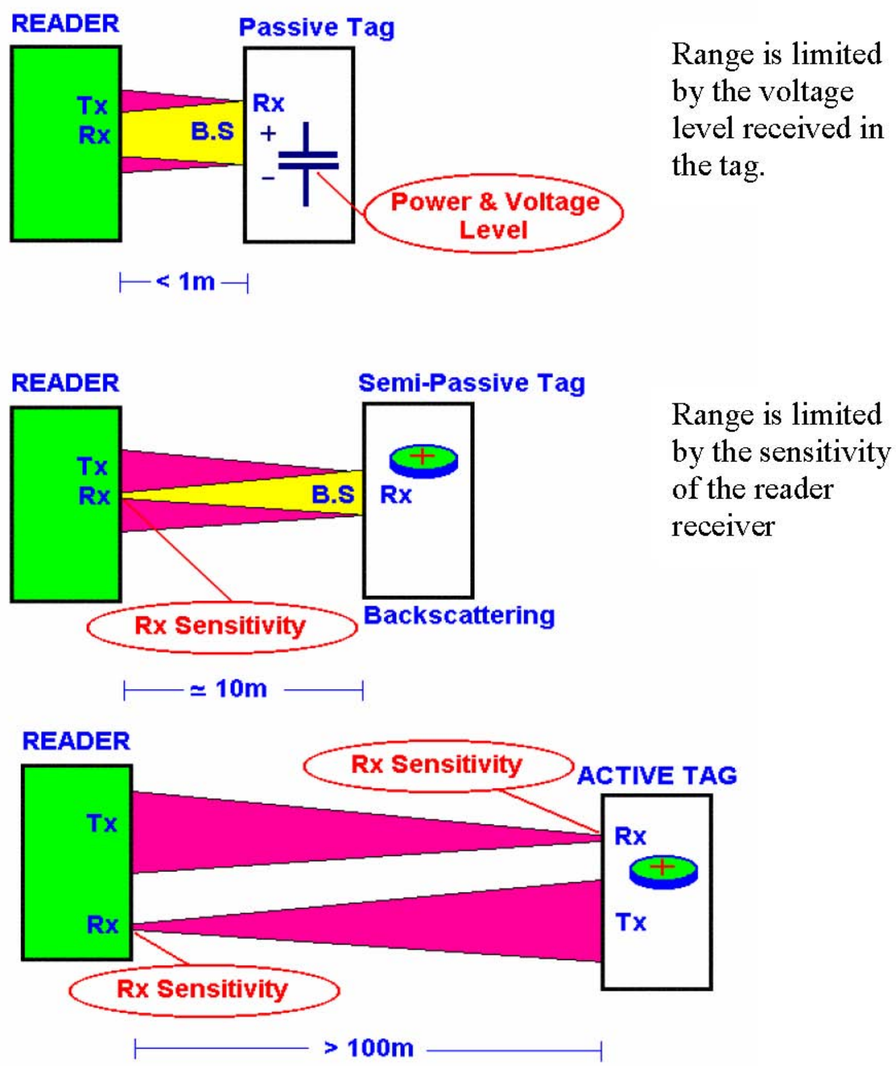

Figure 2: Comparing the range limitations for different types of RFID tag

1.5. RFID Applications

RFID has emerged as the leading solution for many applications. Electronic toll collection, access control systems and vehicle immobilizers are all systems that would not be nearly as efficient or effective without RFID technology. See Table 3 for a listing of key application segments, including representative applications and competing technologies.

Asset management /Inventory control: RFID tags can be permanently attached to capital equipment and fixed assets including pallets, RPCs, cylinders, lift trucks, tools, vehicles, trailers and equipment. Fixed position readers placed at strategic points within the facility can automatically track the movement and location of tagged assets with 100 percent accuracy. This information can be used to quickly locate expensive tools or equipment when workers need them, eliminating labor-wasting manual searches. Readers can be set to alert supervisors or sound alarms if there is an attempt to remove tagged items from an authorized area. By tracking pallets, totes and other containers with RFID, and building a record of what is stored in the container as items are loaded, users can have full visibility into inventory levels and locations. With visibility and control, manufacturers can easily locate items necessary to fill orders and fulfill rush orders without incurring undue managerial or labor time. Shipping & Receiving: The same tags used to identify work-in-process or finished goods inventory could also trigger automated shipment tracking applications. Items, cases or pallets with RFID tags could be read as they are assembled into a complete customer order or shipment. The individual readings could be used to automatically produce a shipment manifest. Manifest information encoded in an RFID tag could be read by the receiving organization to simplify the receiving process and to satisfy requirements like those for advance shipping notices. Having complete shipment data available in an RFID tag that can be read instantly without manual intervention is very valuable for cross dock and high-volume distribution environments. Incoming shipments can be automatically queried for specific containers.

Returns & Recall Management: Companies could supplement the basic shipment identification information by writing the specific customer and time of shipment to the tag immediately prior to distribution. Producing and recording this information would provide several benefits. In the event of a recall, companies could trace specific shipments to specific customers, which would enable a highly targeted notification and return operation and avoid a costly general recall. For general returns, companies could verify that the customer returning merchandise is actually the customer who received it, which would deter diversion, counterfeiting and other forms of return fraud.

Library Information Systems: Tracking a library's assets and loan processing is a very time-consuming process. Traditional bar-coding systems help to improve the process. However, RFID technology offers additional enhanced features such as *efficient processing* (faster and more efficient tracking)*, security, and inventory management* (a few hours instead of week or months for inventory checking).

Table 3: RFID Application Matrix

Application Segment	Representative Applications	Competitive Technologies	Current Penetration	Typical Tag Type
Access Control	Doorway entry	Other keyless entry technologies	High	Passive
Asset Tracking	Locating tractors within a freight yard	None	Low	Active

Asset Tagging	Tracking corporate computing systems	Bar Code	Low	Passive
Authentication	Luxury goods counterfeit prevention	Holograms	Low	Passive
Baggage Tracking	Positive bag matching	Bar Code, Optical Character Recognition	Low	Passive
POS Applications	SpeedPass	Credit Cards, Debit Cards, Smart Cards, Wireless Phones	Medium	Passive
SCM (Container Level)	Tracking containers in shipping terminals	GPS-based Systems	Low	Active
SCM (Pallet Level)	Tracking palletized shipments	Bar Code	Minimal	Active, Passive
SCM (Item Level)	Identifying individual items	Bar Code	Minimal	Passive
Vehicle Identification	Electronic toll collection	Bar Code, License plate, reader systems	Medium	Active, Passive
Vehicle Immobilizers	Automotive ignition systems	Other theft prevention technologies	High	Passive

Source: Allied Business Intelligence Inc.

2. IBS HONGKONG & RFID system

We are positioned to be one of the large suppliers in the RFID market either as a product or as an IP. We have fabricated and tested a couple of RFID ICs and planned to produce RFID readers and tags with sensor interface and eventually single chips consisting of a sensor and an EPC compliant RFID tags.

2.1. PEDM RFID chip (Cronos110)

PEDM has an innovative dual mode (passive and semi-passive) ISO-compliant RFID tag and plans to fabricate ISO and EPC compliant RFID tag with sensor capability. The configurable 64 byte EEPROM memory contained in the chip is organized in 32 words of 16 bits for ID and user applications. The CRONOS110 has a built-in anti-collision protocol which allows an unlimited number of transponders in the reader field to communicate simultaneously. The transmission antenna and battery (in semi-passive mode) are the only external elements required and all the other elements are integrated on chip. The specification of Cronos110 is shown in Table 3.

Table 3: Cronos110 General Specification

General Specification	
Protocol	ISO 18000-4 part 1 / ISO 18000-6 type B
User Memory	48 bytes (user area)
Memory type	64-byte EEPROM organized in 32 words of 16 bits
Communication frequency	2.45 GHz / UHF
Data retention	10 years
Number of overwrites	100,000 times for each address
Ambient temperature in operation	-40°C to 85°C
Modes of operation	Dual mode: passive and semi-passive (battery-assisted)
Die size	< 2 mm2 (now), <1.5 mm2 (next si either passive or active)

Cronos110 is an ultra low power RFID tag which can operate either in passive mode or semi-passive mode. Figure 5 shows the supply connections.

In passive operating mode, the supply voltage is extracted from the RF field and applied to the common circuit blocks (shared circuits between passive and active modes such as bias circuit and clock generator) and digital part. In this mode, the supply node of semi-passive circuits is connected to ground to prevent undesired transitions.

In semi-passive operating mode the supply voltage comes from an external battery and applied to the exclusive semi-passive circuits, common circuits and digital part. The chip uses backscattering concept for both operating modes to reduce the power consumption.

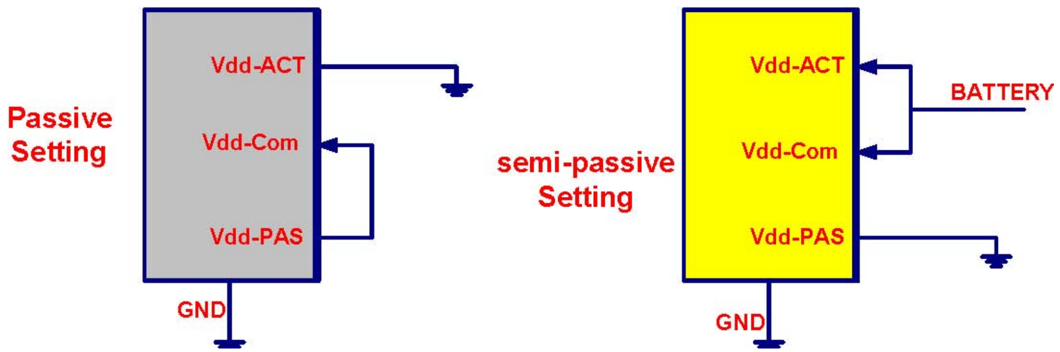

Figure 5: Supply connections for the dual mode RFID tag chip

Figure 6 shows the block diagram of the RFID chip. The building blocks of the analog front-end will be discussed in the following sections.