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EPCglobal Class 1 Gen 2 RFID Specification

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EPCglobal Class 1 Gen 2 RFID Specification

Approved by EPCglobal in December 2004, the Class 1 Gen 2 air interface protocol provides a number of enhancements that will help solidify the adoption of RFID in the UHF band.

1. It establishes a single UHF specification, where previously there were several, including EPC Class 1, EPC Class 0, and two from ISO.
2. It is designed for worldwide deployment, addressing emerging UHF regulations in different regions.
3. It leverages and improves on the best features of preceding UHF specifications, and anticipates a range of future applications and product extensions including higher-function sensor tags.

This paper provides a brief explanation of how Gen 2 improves on previous protocols and the expected impact of these benefits, which include:

- Faster, more flexible read and write speed
- Higher reliability in tag counting
- More robust performance of many readers in close proximity
- Enhanced security
- Extensibility to higher-function tags and systems

Faster, more flexible read speeds

Like people talking in a noisy room, RFID tags and readers can talk fast, and will understand each other in close proximity or in a quiet spot, or they can talk slower, and be understood with more background noise and at greater distance.

First-generation RFID systems generally operate at a single communication speed, appropriate for "typical" conditions. As a result these systems perform well in most applications, providing satisfactory speed and adequate noise robustness.

Class 1 Gen 2 provides four different communication speeds, to provide more flexibility for different operating environments. Running at top speed, Gen 2 systems have the theoretical potential to read over 1,000 tags per second in applications which are well-insulated from RF noise, but also have the option to slow down in noisy conditions and still read 100 or more tags per second with high reliability.

This flexibility is expected to have the biggest impact in regions operating under stringent regulatory limits, particularly Europe and Asian countries considering approaches derived from European regulations. In these regions, the read speed of Gen 2 is expected to be up to twice as fast as Gen 1, with maximum system read rates of up to 500 per second depending on the operational environment.

In applications where the faster Gen 2 communication modes can be used, users should expect to see enhanced system performance and read robustness.

In addition to variable read speeds, Gen 2 sets aggressive targets for the speed at which tags can be programmed. EPC Gen 2 dictates that tags be writeable at a minimum rate of about 5 per second, and sets a target of 30 per second. Hitting this target would allow RFID tag integration and programming on most high-speed assembly and packaging lines.

Robust tag counting – the "Q" protocol and "symmetry"

RFID tags at the outer edge of a reader's range experience only brief and intermittent moments of power from the reader, and are therefore difficult to read reliably. In its "Q" protocol and the use of symmetric persistent states, Gen 2 builds on several principles proven effective in Gen 1 systems to address this challenge.

The "Q" protocol uses short, simple query/ acknowledgement interchanges between readers and tags, so that a tag experiencing only brief moments of power can be read. Implementing "Q", a reader issues a query and each tag responds with a randomly generated number. The reader then issues an acknowledgement that includes a single tag's random number, which prompts that tag to send its ID. This process continues until all tags in the reader's field have been counted. By using random numbers generated by individual tags as the basis for sorting rather than EPC numbers, all tags can be identified uniquely even if the same EPC number is shared among many tags.

To further enhance efficiency and speed, the ability to "quiet" tags after they have been read helps focus a reader's efforts on getting the most difficult-to-read tags at the edge of the field or on an RF-absorptive material. Users familiar with the Class 1 Gen 1 protocol understand how it puts tags to "sleep" after they have been read. With the easy-to-read tags quieted, the reader can focus on only the more challenging tags in the field that haven't yet been counted. To begin a new count or sort, the reader issues a wake-up or activation command, to ensure that all tags will be awake and ready to be read. In practice, Class 1 Gen 1 readers repeat multiple wake-up, sort, sleep cycles to ensure that all tags in a field have been awakened and read in order to complete an inventory.

Gen 2 refines this process by introducing a dual-state, symmetric inventory scheme, which enables a new count to start without tags needing to hear and react to a wake-up command. This both speeds the counting process and helps make sure all tags are counted. Under this approach, a tag changes its state each time it is read. As the reader counts each tag in the "A" state, those tags move automatically to the "B" state. And as each B tag is counted, its state changes back to A. Much like the repeated wake-sleep cycles deployed under Gen 1, a Gen 2 reader repeats counts of A and B tags until all tags in the field have been identified.

Gen 2's combination of "Q" and "symmetry" are expected to deliver improved read robustness in many applications.

Mitigating reader interference – dense reader operation

In terms of RF power transmitted, RFID readers "shout" their commands to tags, and in doing so provide enough energy to the tags that they can "whisper" back their response. Too many readers operating in close proximity and shouting at the same time can drown out the whispered responses of the tags.

Existing Generation 1 systems use conventional approaches to enable multiple readers to operate in close proximity. In the U.S., the wide UHF bandwidth allowed by the FCC combined with frequency hopping provides a good solution, and one that is also "friendly" to other radio devices sharing that UHF bandwidth. In Europe, the frequency bandwidth available for RFID is relatively narrow, and tight regulations govern the use of the UHF spectrum. The operation of multiple readers is possible under these restrictions, but readers are required to "listen before talk" – that is, they need to determine that a channel is not already in use before they start communicating on that channel. This severely limits system performance for some applications.

Gen 2 seeks to improve "dense-reader" operation in several ways. First, it is designed to use available RF bandwidth as efficiently as possible. The baseline RF signaling approach is relatively quiet, particularly compared to some preceding protocols such as EPC Class 0, and the Q protocol sorts tags not only quickly but with minimal data exchange required between the reader and tag.

Second, Gen 2 introduces a new radio signaling mode that can isolate tag responses into a side channel where they can be better heard. Specifically, "Miller sub-carrier" rates allow the reader to specify side channels of varying widths, according to the overall environmental noise conditions. The narrower the side channels, the easier it is for the reader to focus in on what the tags are saying. Gen 2 also provides for an "FM0" signaling mode that can enable faster reads than the Miller sub-carriers. This mode is relatively susceptible to RF noise; users should expect that noisy conveyors, electric equipment, or even fluorescent lights may create enough interference to challenge use of this mode.

Third, Gen 2 calls for three modes of reader operation: single reader, multi-reader and dense-reader. Under the dense reader mode, reader transmissions are segregated into distinct RF channels offset from the response channels of tags to keep tag transmissions from colliding with reader transmissions. In Europe, for example, readers would be confined to even-numbered channels and tags to odd-numbered channels.

Finally, Gen 2 ensures accurate reads in noisy conditions by implementing a similar data verification approach as Class 1 Gen 1, thereby ensuring the "ghost read" problems experienced with Class 0 Gen 1 systems are avoided. In addition to verifying read data, Gen 2 adds a feature that confirms when tags have been written correctly.

Using some or all of these Gen 2 features, users will be able to develop tailored solutions for their applications, even ones requiring many readers operating in very close proximity.

Parallel counting, by multiple readers – reader "Sessions"

Gen 2 also anticipates situations where there are several readers simultaneously communicating with the same tag – this is a variation of the dense reader challenge. Under the dual-state symmetric tag sort approach outlined above, there is a risk that one reader will change a tag's state in the middle of another nearby reader's inventory cycle, thereby causing the second reader to miss the tag. In many situations, this is not a problem; application software often needs to know only that an item has been read by one of several readers on a store receiving dock, for example; which particular device read the tag is not important. For applications that depend on knowing which specific reader has read a tag – e.g., store shelves, warehouse putaway locations – Gen 2 provides a solution.

Using "sessions" it is possible for a single tag to communicate with two or more readers in parallel. Readers can be assigned to use any one of four logical sessions for reads. In a warehouse, for example, readers at alternating dock doors could use different sessions to avoid interfering with each other's transactions. Mobile readers, such as handhelds and forklifts, could be assigned to a third session. An outside vendors' hardware might be assigned the fourth session. This way, up to four separate identifications of the same tag can be undertaken simultaneously without interference – and without having to wait for any one reader to complete its sort. The monitoring and allocation of sessions can be managed via readers or via a central control point.

As readers and applications proliferate, this interleaving functionality will likely become increasingly important.

Enhanced security and privacy

With some incremental expense for additional memory to the tag, Gen 2 takes a more traditional approach to security than Gen 1 protocols by using 32-bit passwords. These passwords can be used for activating kill commands to permanently shut down tags, as well as for accessing and relocking a tag's memory.

For protection against eavesdropping on tag reading by unauthorized devices, the Q protocol never requires the communication of an entire tag ID over the air. Even if a receiver is positioned to listen to a reader's communication with a tag population, the signals are so scrambled it is virtually impossible to determine the EPC numbers.

Gen 2 also introduces handle-based commands for securely interacting with tags. When a tag is inventoried, it can randomly generate a 16-bit number, or "handle", which can be used by a reader to enhance the security of read, write, and erase commands.

Extensibility to higher-function systems

Building on the original specification framework started at the Auto-ID Center, the Class 1 Gen 2 specification anticipates and plans for higher-function systems. Class 2 systems add larger memory tags, higher levels of read-write functionality, and potentially higher security. Class 3 systems include a battery on the tag for longer read ranges and to support the ability of the tag to communicate sensor-based data such as temperature, pressure, shock, and many other types of sensors. Tags of all these Classes will be readable by EPC readers, making it possible to create more and more powerful functionality in supply chain and other applications.

Comparison of EPC Class 1 Gen 2 and Class 1 Gen 1 Features & Performance

FEATURE	CLASS 1 GEN 2	CLASS 1 GEN 1
Read speed (Reads per sec running sort protocol; field performance highly dependent on application)	• Up to 880 (US FCC) • Up to 450 (EU ETSI) • Speed adaptable to RF noise in environment	• Up to 230 (US FCC) • Up to 115 (EU ETSI)
Write speed (for 96-bit EPC)	• 5 tags per second minimum • Rewriteable many times	• 3 tags per second • Rewriteable many times
Tag sorting protocol	• "Q" protocol: a random number algorithm with 2 persistent symmetric states (enables counting of multiple tags with same EPC, and on-the-fly adaptation to size of tag population)	• Binary tree algorithm with persistent sleep/wake states
Tag data verification	• 16-bit CRC for reads and writes	• 16-bit CRC for reads
Multiple reader operation	• Frequency hopping (US FCC) • Listen-before-talk (EU CEPT) Dense reader modes (channelization, variable subcarrier modulation) • Four reader "sessions", allowing parallel communication by multiple readers with one tag	• Frequency hopping (US FCC) • Listen-before-talk (EU CEPT)
Security	• 32-bit lock and kill passwords • Option for "handle"-based communication	• 8-bit kill password, with lockout after incorrect queries
Extensibility	• Up to 512 bit item ID • Unlimited user memory • Anticipates Class 2 & 3 systems	• Up to 96 bit item ID

The Gen 1 to Gen 2 Transition

The largest global drivers for RFID, mandates from Wal-Mart and the U.S. Department of Defense, are well underway with integration of RFID into supply chains and daily operations of suppliers. These deployments are based on RFID technology and products that are well established and broadly available today. Both of these organizations have established that EPC Gen 1 hardware meets their current application requirements. As such, Gen 1 will continue to be an allowable technology for these mandates for some time to come, and will be accepted in their systems for at least a year after Gen 2 is first permitted.

So how should end users who have already deployed Gen 1 systems plan to transition to Gen 2? The answer depends on the amount of internal resources available to apply to RFID. Users with large budgets, dedicated labs and staff may decide to be part of one or several beta tests of Gen 2 hardware, so they are ready to deploy as soon as Gen 2 product becomes available commercially. Users with more limited resources can rely on the efforts of EPCglobal and other users to test and tune the new systems for interoperability and reliability, thus focusing near-term on effectiveness and efficiency of current deployments. These users can then transition to Gen 2 when the cost and performance, and interoperability of the new Gen 2 tags proves superior to Gen 1. Most users can take advantage of software upgrades that are expected to be available for Gen 1 readers to make them compatible with Gen 2.

Users who are just getting started with RFID face a different choice. One option is to get started with Gen 2 products as they become available over the balance of the year, which obviates the need for a future transition from Gen 1. Alternatively, these users can initiate an implementation with Gen 1 hardware and tags for which the performance, cost, and availability is well known. Given the complexity of some RFID deployments, this can be a more predictable approach. Users choosing this option can deploy Gen 1 readers that are Gen 2 upgradeable, and transition to Gen 2 tags when they are available with the necessary design, performance, and cost parameters.

The next several years will be exciting as the promise of Gen 2 is realized. Every iteration of hardware – tags and readers – will move closer to achieving the great potential inherent in the specification. With UHF RFID already well established and ramping, the EPC Class 1 Generation 2 standard will ultimately be instrumental in extending its global coverage and achieving the value the RFID industry is striving to deliver.

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