BLE and energy harvesting enable low-cost, maintenance-free active RFID systems

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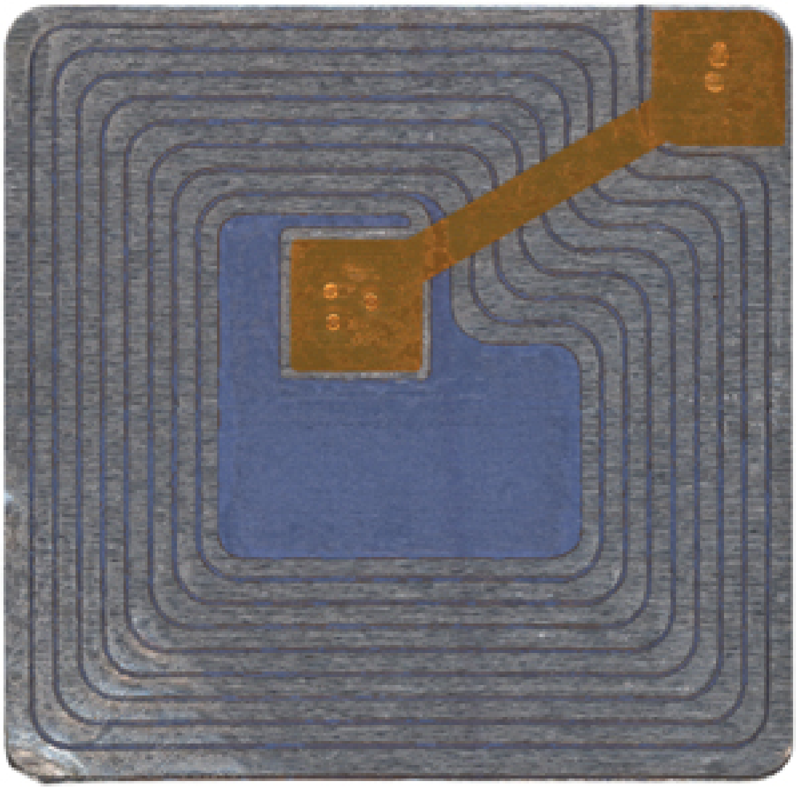
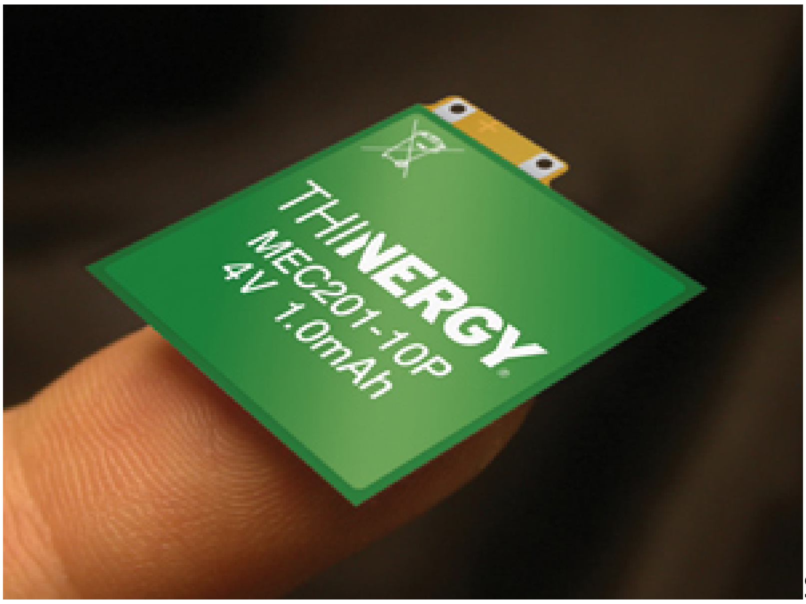


Radio frequency identification (RFID) has long been a valuable tool for asset management, allowing objects to be identified, tracked and/or located. Limitations in the accuracy of passive tag systems along with high tag and battery maintenance costs in active systems have limited the adoption of RFID in broader applications. An ideal combination of RFID features would combine the higher reliability and information fidelity of active systems with the lower costs associated with passive systems. With the introduction of low-power radio frequency communication protocols, such as Bluetooth Low Energy (BLE), active tags can be powered using solid-state rechargeable batteries. Recharge energy can be provided using energy harvesting techniques that scavenge energy from the environment. The result is a relatively low-cost active tag asset tracking system that can operate for decades without maintenance.

The “tags” used for RFID fall into two general categories: passive and active. The passive tags require the use of a reader to produce energy in the form of an RF field. Passive tags that are exposed to the reader field essentially reflect the RF signal from the reader and encode information in the reflected signal to uniquely identify the tag. Battery-assisted passive (BAP) RFID tags perform the same task but require lower field strength from the reader by leveraging a low-cost printed battery placed within the tag that amplifies the reflected energy. This increases the reliability and useable distance from the reader in passive systems. In both passive cases, the distance at which the tags can be read is fairly limited because of the near field limitation and reflected field strength. Passive tags also tend to be fairly low-cost devices, consisting of a printed antenna and small integrated circuit. In situations where the passive tag is oriented in certain ways, or is obscured from the RF field, tag acquisition is often unreliable. This is what prevents passive tags from being used in applications, such as point of sale activities for example, where a shopper could push a grocery cart through a reader “portal” and have all the items in the basket detected in one pass. Items in the cart are often missed by the reader field or are read multiple times. Using BAP tags in this particular situation could improve the read accuracy, but BAP tags often fail due to the relatively short lifespan of the printed battery. This is especially true when tags face extended temperature ranges, which is often the case in warehousing operations. These types of issues have limited the acceptance of passive RFID systems for use in more types of applications.

Active RFID tags include an energy storage device such as a coin cell battery and an active transmitter. They can produce powerful RF signals that can be detected at great distances – up to several hundred meters. Through the use of RF protocols, such as Zigbee, active tags can correspond with the reader or host system, greatly improving the reliability of the tag acquisition process. Sensors such as motion, temperature, shock, vibration and location (GPS) can be added to active tags to increase the data gathered during tracking. However, the added sophistication of active tags makes them much more expensive than passive tags. Additionally, for the tags to run for extended periods, they require battery maintenance to replace or recharge the battery. The traditionally applied RF protocols used in most existing active systems consume larger than desired amounts of energy, which further increases the battery size and maintenance requirements. As a result of these issues, active RFID systems have been introduced in relatively limited volumes and are applied to higher-value asset tracking and management than passive systems.

To create the ideal RFID system, however, a combination of the low cost associated with the passive RFID system with the reliability and capabilities of the active RFID system is needed. This requires that the battery system with the active tag be made as low cost and maintenance-free as possible. Lower power usage within the tag needs to be achieved in order to extend the serviceable life of the battery. This can be accomplished by reducing the power requirements of the radio protocol; using passive sensors that do not require active current such as micro switches; choosing low power electronics; and properly coding the firmware running on the tag to keep the tag in the deepest sleep state possible between active periods. Additionally, eliminating the classic “clamshell” enclosure with battery door and battery contacts by using a permanently embedded rechargeable battery will further reduce the cost of the active tag. Permanently embedded rechargeable batteries can be recharged by adding a low cost solar panel to gather ambient light, or by including a small printed antenna to gather intentionally projected RF energy. The latter approach is useful in situations where assets will be kept in dim or dark warehouses for long periods.



Starting with the RF protocol, BLE is a good example of an extremely low-power communications protocol that will be widely available in a host of products from cell phones and laptop computers to common appliances. Such devices are labeled Bluetooth Smart Ready Devices and will be able to communicate directly with BLE- enabled tags. A sub-standard of the Bluetooth 4.0 specification, BLE uses power levels that are often one-tenth of the power levels used by current common standards. Tens of thousands of transactions between the host and an active RFID tag running BLE can be achieved using a single milliamp hour of battery capacity. It should be noted, however, that BLE operates on a 2.4-GHz frequency and might not be ideal in situations where assets need to be tracked through walls or other obstructions. However, the ubiquitous Bluetooth devices found today in handheld devices, such as phones and tablets, makes it extremely easy to develop asset tracking applications that can be quickly deployed without additional infrastructure or hardware beyond the active RFID tags. Part of the BLE standard also includes the use of RSSI, or received signal strength indication, which can be used to determine how far away the tag is from the host reader. This feature is provided within the host device and does not incur an energy cost within the tag. Additional information can be encoded within the BLE transmission, including various sensor devices that are defined within the specification. This allows the active tag to provide information on the condition or treatment of the asset in addition to presence and location.

Next, choosing a rechargeable battery, such as the THINERGY Micro-energy Cell (MEC) available from Infinite Power Solutions, Inc. (IPS) produces a power source that will never need to be replaced for the lifetime of the active tag, and most likely the asset being tracked. MECs are extremely thin and take up little volume within the tag. They can also be recharged hundreds of thousands of times have extremely low self-discharge rates; and can withstand broad temperature ranges with minimal degradation. This implies that the battery and electronics can be permanently embedded into the tag, or even the asset. Low-cost manufacturing in this manner is accomplished by simply over-molding or potting the battery and the electronics to form a permanent, fully enclosed active tag. This method reduces the assembly and component cost associated with the assembly of traditional clamshell style injection molded enclosures, eliminating battery contacts, battery door, assembly screws, etc., while greatly decreasing overall tag volume.

Finally, the addition of an energy harvesting device such as an inexpensive solar panel or RF harvesting system (like those produced by Powercast Corp.) within the unit allows the active tag to gather energy autonomously. Small, inexpensive, low-light amorphous solar panels can be embedded into the tag as part of the over-mold. The average current usage of a modern real-time clock or microcontroller in a deep sleep state using passive sensors such as microswitches for interrupt activation can be maintained in the tens of nano-amps. Combined with the relative infrequency of tag read cycles required for asset tracking, the average current used by the tag can be maintained well below 1µA. This implies extremely low average energy harvesting production to keep the tag operating indefinitely. In warehousing situations where even lighting is hard to come by, providing an intentionally projected RF energy source on an intermittent basis will keep low power active tags operating indefinitely.

The convergence of the BLE protocol with availability of long-lived energy storage devices like IPS' THINERGY MECs has enabled a new generation of low cost, maintenance-free active RFID tagging systems. This is a major milestone, since these active tags will be able to provide the reliability and security of existing active RFID systems without adding the cost and requirement to install sophisticated reader systems, since the readers will be included within existing Bluetooth Smart Ready-enabled devices. In summary, these new active RFID systems can now achieve the low cost of ownership advantages afforded by passive systems while delivering the superior reliability associated with the higher cost, maintenance-intensive active RFID systems currently on the market.

Joe Keating studied electrical and computer engineering at The University of Colorado, Boulder (BS, 1990). Mr. Keating began his career as an embedded electronics design engineer. Joe has over ten years of experience in battery design development and applications support. Currently, he is the Sr. Director of Applications Engineering at Infinite Power Solutions, Inc., in Littleton, Colo.