Producers, wholesalers and retailers of perishable products such as food and pharmaceuticals have enormous value tied up in assets that become worthless if they are not kept in a precisely controlled, cool environment. The logistics industry has therefore developed elaborate and expensive systems for ‘cold chain monitoring’. These let distributors of perishable goods continuously monitor the conditions in which goods are held, and rapidly intervene when these conditions fall outside their specified thresholds.

The semiconductor industry, however, has a habit of disrupting large, expensive and cumbersome technologies such as this, often replacing them with a smaller, cheaper and better alternative. This might now be possible in the field of cold chain monitoring, because of the introduction of a new type of component: the sensor-enabled (sensory) RFID tag. This article explains how.

**RTLS-based systems: too big to fail?**

In a process lasting many years, the logistics industry has spent billions of dollars creating technology, and a supporting infrastructure, to provide for constant monitoring of perishable goods in storage and on the move. Now the industry has to face the prospect that this investment could be made obsolete by new RFID sensor chips and RFID readers costing a few tens of dollars.

Of course, large corporations can afford complex monitoring systems which combine real-time location systems (RTLS), software, active RF tags, wireless communication points and GPS tracking, even though they are expensive and require constant maintenance. The total cost of ownership also includes airtime for GPS satellite positioning and a data link via cellular telephone networks, plus the hardware and software costs for outfitting and maintaining every container or trailer unit, and installing wireless access points in every distribution location.

Such systems provide information that allows immediate intervention when faults occur. Unfortunately, although real-time monitoring might appear to offer a means to ensure zero wastage of perishable goods, in practice there is no cast-iron guarantee. For instance, in-transit problem mediation more often leads to delay as operators seek the source of the
problem than to a swift resolution. The back-up systems (such as mobile maintenance crews) required to resolve cold chain problems are extremely expensive and do not always work effectively.

But when the logistics industry was first deploying cold chain monitoring technology, this complex and cumbersome infrastructure was all that was available. At the time, it appeared to offer the means to protect all inventory all the time.

In fact, it might now make more financial sense to implement a simpler method of cold chain monitoring based on sensing temperature and other parameters individually at each package, drawing on existing infrastructure used to implement RFID systems. Such technology lacks RTLS capability, and so users must accept a small amount of wastage when fault conditions occur and intervention is not possible to rescue the goods at risk. The savings from operating a cheap and simple monitoring infrastructure would far outweigh the cost of a small amount of extra wastage.

**Low-cost, local cold chain monitoring**

The concept of the low-cost (a few cents), disposable passive RFID tag is well established in the logistics industry. Passive RFID tags may be read by an RFID reader: communication is achieved when a passive tag modulates the backscattered RFID energy broadcast by the reader. Passive tags therefore need no independent power source, and have a theoretically infinite operating life.

Conventional RFID passive tags contain a small non-volatile memory that, as the name RFID suggests, stores a unique identification code.

But what if an RFID tag was also able to function as a data-logging device as well? This is the promise of a new generation of sensor-enabled RFID tags developed by ams. Such a device could monitor the condition of individual packages during transportation or in storage. Environmental information such as temperature, vibration or humidity could be measured and logged (see Figure 1).
Because it would use existing RFID technology and equipment, such a system would be simple and affordable for companies to implement. But by adding an on-board temperature sensor and EEPROM for logged data, as well as a low-power interface to external sensors (see Figure 2), such a device provides the means to monitor the environmental conditions of every package individually.

While existing technology monitors conditions at the container level (for instance, measuring the temperature inside a truck’s refrigerated container or inside a warehouse), a sensory tag can measure the temperature and other parameters at the level of the individual package, which offers more accurate measurement.

This combination of improved performance and lower cost – so often offered by the semiconductor industry in other industries – could now transform the operation of cold chain monitoring of perishable goods, providing a low-cost means to manage the cold chain while maintaining high standards of efficiency and quality.

Two modes of operation
The concept of a sensor-enabled RFID tag can be implemented in two different ways. The mode closest to that of a conventional RFID tag is the fully passive mode. Here, the sensory tag has no independent power source, which means that no real time clock (RTC) function is available. When woken by an RFID reader, it draws a typical current of 4mA from the incoming RF field to harvest energy. Of this, only 150µA is used to operate the sensor interface and built-in functions such as a temperature sensor (see Figure 2).
So in this mode, data logging for the purposes of cold chain monitoring occurs when the package is interrogated by a reader, which initiates temperature logging and provides a time stamp. The tag controls whether it takes data from an internal or external sensor. The logged data are protected with passwords to prevent manipulation or unauthorized use of the data.

Fig. 2: a sensory tag operates like a conventional RFID tag, but provides a built-in temperature sensor and an interface to a choice of external sensors

The sensory tags may also work in semi-passive mode (also known as battery-assisted passive or BAP). Here, a small battery provides power for autonomous data logging, time-stamped by the on-chip RTC. The typical lifetime of the battery is between 1 year and 1.5 years, although this depends on the battery type and the logging intervals.

Choice of sensory tags
ams today offers two sensory tags suitable for cold chain monitoring; both include an on-board temperature sensor which can measure from -40°C to +125°C.

The SL13A, which provides a high-frequency (13.56MHz) air interface, is compliant with the ISO15693 and NFC-V standards. The UHF (860-960MHz) SL900A complies with EPC Gen 2, Class 1 and Class 3 standards. Both devices are also compatible with the cool-Log™ commands.

The simplest use case for these devices is temperature logging and identification in fully passive mode (that is, in the presence of an RFID reader). This requires the use of the standard commands for tag singulation, and the custom ‘Get Sensor Value’ cool-Log command used for temperature conversion.
If the tag is required to log data when a reader is not present to provide an RF field, a battery must be connected to the SL13A or SL900A. A 1.5V or 3V (single-cell or dual-cell) battery may be used.

If a thin and flexible battery is used, blister pack-type transponders may be manufactured on a flexible substrate; this implementation is the cheapest to manufacture, and such tags are disposable. If the transponder is to be re-usable, a button cell and rigid PCB substrate are recommended.

For temperature logging in BAP mode, the system will use the standard RFID commands for tag singulation and custom cool-Log commands such as:

- Set Log Mode
- Initialise
- Start Logging
- Stop Logging

SPI interface to microcontroller

Both the SL13A and the SL900A provide a Serial Peripheral Interface (SPI) port to connect to an external device such as a microcontroller (see Figure 3). This extends the range of functions available in cold chain monitoring applications beyond the sensing, data logging and identification functions provided by the stand-alone RF tag.

In particular, the MCU can provide a connection to a cellular transceiver for remote direct access to the logging data. It also allows for easy setting of the device’s registers and functions. The MCU may also be programmed to support an alarm system and functions that calculate shelf life.

The SPI can be used to read and write to the embedded EEPROM, and as a test interface on the production line for calibration and user ID programming, and to support non-standard RF protocols.
Fig. 3: connecting an MCU to the RFID tag via SPI provides great versatility in cold chain applications

**Conclusion**

The ams sensory tags, the SL13A and SL900A, enable cold chain operators to automatically track, monitor and record sensory information, such as temperature, pressure, humidity or vibration. They can also be configured to automatically execute an alarm or notification when a critical condition occurs.

This event-driven capability enables cold chain and logistics companies to determine the conditions of the materials used in a non-invasive and practical way, and provides a dramatically simpler and cheaper alternative to the elaborate cold chain monitoring infrastructure used today.

[ENDS]