 By Graham Prophet, Editor

RFID and the smart label; bye-bye bar code?

UNUSUALLY, A MARKET SECTOR POISED FOR HIGH GROWTH RATES THAT IS NOT PRIMARILY DRIVEN BY INNOVATION AT SILICON PROCESS LEVEL; INSTEAD, INGENIOUS PACKAGING TECHNIQUES AND SYSTEM INNOVATIONS WILL PROLIFERATE THE SMART LABEL. YOU MAY NOT THREATEN THE HUMBLE BAR CODE ON PRICE ALONE, BUT YOU CAN OFFER A WHOLE NEW RANGE OF FEATURES AND END-CUSTOMER SERVICES

Contactless, positive identification and remote data readout has absorbed a considerable amount of ingenuity over the years; its most familiar form is probably the ubiquitous printed bar code, in its UPC (universal product code) and other guises. But there are others, most notably radio frequency identification - RFID - and a number of developments in that field look set to spark very rapid growth and proliferation of RF-based applications.

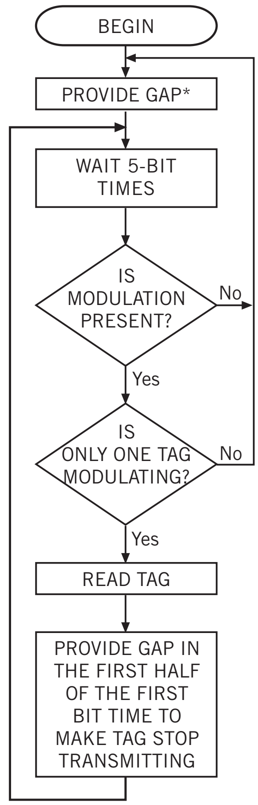
RFID systems exist in many forms, in varying degrees of complexity and operating in a wide range of frequency bands from LF through to the shared ISM (industrial, scientific and medical) band at 2.4GHz. In this article, we limit ourselves to discussing those systems in which the data is held in passive transponders operating at 125, 134.2 kHz or 13.56 MHz. In this context, “passive” means that the device that holds the data has no battery or other power source of its own. Although powered only by the electromagnetic field generated by the reader that interrogates them, today’s transponders are anything but passive in the sense of their own complexity, allowing not only straightforward data readout, but added features such as sensor input reporting and data encryption.

The RFID transponder market is complex and multilayered. It is underpinned by a (relatively few) number of semiconductor companies producing chips for both the transponder and fixed reader parts of the identification system. An essential part of the enabling technology that goes to make up a viable ID system is the packaging and interconnect that immediately surrounds the transponder chip, and components such as the antenna coil that is involved in nearly all of the transponder designs. Some of the semiconductor companies are involved in this next-level packaging and produce not only silicon but also sub-assemblies for transponder manufacture. A large number of suppliers is concerned with taking bare dice and packaging them either into finished, end-user transponder products, or into intermediate subassemblies. Further along this food chain there are systems integrators, bundling customised readers and transponders into product packages for specific applications. If you are inspired to carve out a new market niche with an RFID product, you are unlikely just to buy chips from a semiconductor supplier and assemble them through conventional manufacturing techniques; specialist intermediaries in packaging technology will be involved.

MATURE RFID MARKETS

Chief among established applications at present are access control products and automotive immobiliser systems. Access control transponders are frequently packaged in "smart card" format, while the vehicle immobiliser systems take the form of an ignition key with embedded transponder chip, without which the vehicle systems cannot be activated. One of these is a one-to-many, readers-to-transponders, system: the other operates one-to-one as there is a dedicated reader in every vehicle that reads just one key.

Figure 1



*Gap = lack of RF carrier signal = 60µs±20%

Anti-collision schemes aim to prevent multiple tags in the same reader field from all responding at once - this is Microchip's algorithm

Both, however, employ the same fundamental technology. The reader generates a continuous RF field in the region where the transponder is to be interrogated. The transponder carries a coil that couples to the field and extracts energy from it; the chip rectifies the RF and uses that dc to power its own operation. With greater or lesser degree of sophistication, and with a variety of possible modulation schemes, it frames its data and modulates the RF signal in the coil. This modulation is coupled back into the reader's output coil, and the reader detects the data as a perturbation in its own signal level. A typical signal level is quoted as 60dB below the carrier. The system can be modeled as a (very) loosely coupled transformer. The essence of chip design for RFID systems lies in what can be done, in an acceptable read time (typically tens of milliseconds), on a power budget of the few microwatts obtained from the field. For this class of unpowered transponder or tag, reading range is typically up to 30 - 50 cm.

Those two existing volume applications also illustrate some of the variables of RFID systems. The ignition key format is very limited in its scope for size and geometry of pick-up coil winding; it must fit within the key and also be low in cost, as is invariably the case for automotive applications. It is, however, in a close and predictable geometrical relationship to the corresponding reader. The smart card presents a relatively favourable geometry for the coil, with a reasonable cross section across the axes of the card; but it will be waved at an arbitrary distance, and in arbitrary orientation, at the fixed reader in order for its user to gain the access it permits.

DATA PROTOCOLS

You will see chips that use a variety of coding schemes for their data streams; in the simplest, the data is simply amplitude modulated on to the carrier wave in a serial, non-return-to-zero (NRZ) fashion. As with any other data transmission, more sophisticated coding schemes can be applied to give increased data rate, or greater immunity to noise. You'll find that the clock that's used to read out the data is derived by dividing down the carrier (hence you'll see f_c/n where n can take a variety of values, in specifications). Power budgets don't allow very much more sophistication in the coding, however; Manchester-coded data is as far as most vendors go. Modulation schemes used range from frequency- or phase-shift keying, down to straight amplitude modulation by the data.

Other variables to look for include the length of the stored bit stream; beyond that, more recent introductions have added new facilities, as higher device counts and advances in low-power silicon processes have allowed more to be done in limited silicon area and with the available power budget. Options you'll see include read-only, or read-write (R/W chips having on-board EEPROM as they spend most of their time unpowered), and within the read-only types, the option to have the identifiers programmed when delivered, or to program them during assembly. All of the usual arguments for field programmable vs. preprogrammed apply here; for example, the convenience of holding "blank" parts, against the cost of programming as part of product manufacture. Further options include encryption; several vendors offer public-key verification algorithms to allow their chips to be used as anti-counterfeiting measures. As with the read/write chips, the verification transaction is two-way, with data being passed to the tag by a modulation initiated by the reader. An important option is anti-collision; a system that is required to read the data from multiple chips that are all within range of the read device requires some method of preventing more than one tag from responding at a time.

LABELS: THE UNTAPPED MARKET

Applications that are expected to form the basis for rapid growth in RFID systems are largely based, in one form or other, on labeling and the "smart label". Viewed as highly attractive potential business are tracking applications such as postal services and airline baggage handling. Baggage handling is often cited as an obvious and high profile application; automating it has been difficult; the technology in use today, a mix of bar-coding and manual handling, has a significant error rate (as frequent international travelers will know!); the intrinsic value of the items labeled is high, and so is the cost of rectifying errors; all of which tends to support the idea that this application could sustain a moderate cost-per-label for a disposable device. Nevertheless, the big factor weighing against RFID's introduction to airline baggage is the need for universality and interoperability, in an environment where standardisation efforts have been very limited (see sidebar, "ISO is go").

Cost is of course a critical dimension in the proliferation of RFID systems. The ultimate objective - in one direction, at least - might be viewed as a tag so cheap that it could replace barcoding on everyday supermarket items. This would enable, given suitable anti-collision strategies, scenarios such as an entire trolley full of purchases to be priced in a single scan. It is fair to say that pricing at that level is some way off. Vendors are also reluctant to be drawn on "target pricing" as viable tag pricing is highly dependent on the value of the tagged item in the end application. Today, bare tag chips are in the sub-1euro range; depending on packaging, format and sophistication, assembled tag prices in the one-to-several euro range. But with new developments, anticipated pricing is such that you can look at one-time RFID tags (for example, combined price/security labels) to attach to items with values in the 10 - 20euro range, or even lower values if tracking an item through repeated transactions is the objective (tagging of library books or rental videos). Price may not be the critical path; as with baggage handling, or postal parcel tracking, improved service may offset a higher system cost.

AT A GLANCE

- ▷ Smart label applications look set to drive more widespread use of RFID.
- ▷ Innovations in basic features are slowing; packaging and overall systems cost are dominant.
- ▷ With the prospect of millions of disposable tags, environmental considerations apply.
- ▷ Cost alone need not be a limitation; RF tags can offer new and combined features over other solutions.
- ▷ New standard ISO 15693 may speed acceptance where interoperability between vendors' tags is an issue.

SIMULTANEOUS READING

Tags for advanced applications can use a variety of anti-collision algorithms. Figure 1 is Microchip Technology's algorithm; when the system detects modulation from more than one tag, it pulses the detecting RF field off, which tells all the tags in the field to stop responding for a set time; they then respond separately at discrete intervals. However, multiple responses is not the only effect of having multiple tags in the field. Because of the coupling of the reader and tag coils, there can be a detuning effect of multiple tags that can reduce range. Microchip's response to this is to add, in its latest MCRF 355 device, a "cloaking" effect. Most tags modulate the RF field by switching a transistor connected across the tag's coil, or part of the coil in the case of tapped coil. The tag's coil is frequently tuned by a capacitor that may be internal or external to the chip (see, for instance, Fig. 2). In the 355, Microchip has split this capacitor into two series connected capacitors, and places a switch across one of them. Modulation is by shifting the tuned frequency of the antenna coil out of the band of the energising field, and the coil antenna can be left in the detuned state to "hide" it from the reader when other tags are being interrogated. This scheme also minimises ringing effects from coil switching, which can be a problem due to the higher Q factors possible with coils for 13.56 MHz operation, Microchip adds. Chip-on-board packaging (the MCRF 355/6C) is the latest addition to Microchip's range of tag chips, which includes both LF and HF types, and provides for factory or user programming, read-only or read/write, en-

ISO IS GO

RFID has not been blessed with many standards, and it's a debated point whether or not this has held back its progress. In the last few weeks, however, the field has passed a significant hurdle on the way to acquiring an international standard. A unanimous vote by the International Standards Organization (ISO) decided to make ISO/IEC 15693-2 an International Standard.

ISO 15693-2 is a communications protocol proposed by Texas Instruments and Philips Semiconductors in November 1998, that defines data coding and modulationbetween the RF tag and reader in a 13.56 MHz system; it officially becomes an International Standard (IS) when published by the ISO Secretariat in the next few weeks.

For end-users implementing 13.56 MHz vicinity cards in different applications and smart label technology in parcel shipping, airline baggage tagging, supply chain management and other item management applications, the ISO vote means that RF tag and reader ICs using the ISO 15693-2 protocol will be compatible. ISO 15693 compatible smart labels from any manufacturer should be readable by any ISO 15693 reader.

TI has said that it sees the move as an important catalyst to further development of RFID systems that require interoperability, and one that will lead to product proliferation and a wider choice for integrators and end users.

Philips says that 13.56 MHz industry groups are already recommending 13.56 MHz technology for RFID smart label systems. The International Air Transport Association (IATA) recently voted in favour of using 13.56 MHz for RFID airline baggage applications and has established a Radio Frequency Working Group (RFWG) to oversee the introduction of 13.56 MHz applications into the airline business.

The existence of such a standard also tells you what to avoid if you need to build a system that must co-exist with a tag-reading infrastructure, but operate separately and independently from it. Using a sufficiently different frequency, or modulation scheme, or coding system, will allow you to build a system that will tolerate "seeing" tags from the standard system pass by, but will not generate false reads by interrogating them.

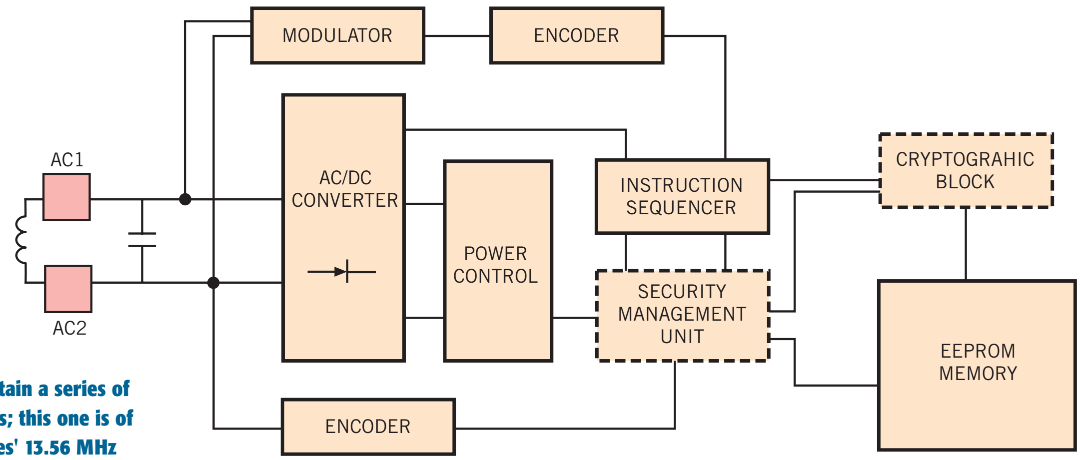


Figure 2

Tags typically contain a series of standard functions; this one is of Inside Technologies' 13.56 MHz devices.

cryption and sensor input. The COB packaging results in a module 6mm × 10.2mm × 0.43mm thick, including the two capacitors, that only requires a single coil to be connected to two pads to make a complete tag. In 10k quantities, the module is priced at $0.75 each. Microchip sees a steep rise in "item-level" tagging applications in the last year and believes that most of what the industry has been waiting for RFID to accomplish is now here.

At Philips, RFID Product Line Manager Christoph Kauer also sees a sharp division between mature sectors - such as vehicle immobilisation - and markets only just beginning, such as smart labeling. Philips only makes and ships silicon, and most of its product (in common with other silicon suppliers in this field) is shipped as sawn wafers. The integrators and tag builders, Kauer believes, are not yet ready to manufacture labels in multiple millions: but if they are not at the 10^8 level, he says, they are already at the 10^7 level. Philips' most recent introduction to its range of ID chips is in the 13.56 MHz I-Code family; I-Code 1 HC allows smart labels as small as 2cm x 2cm, with a typical thickness of less than 0.5 mm, to be manufactured. These types of labels are required in applications such as the identification of CDs and videotapes, where the detailed product information stored in the label helps to reduce the risk of piracy and theft. Dirk Morgenroth, Philips Semiconductors' Marketing Manager for I-Code, said, "The I-Code 1 HC enables RFID technology to be used in applications where the small labels required limit the possible size of the inlet antenna."

The I-Code 1 HC has an input capacitance of 97pF which is needed to support small-sized antennas on smart labels. It contains 512 bit read/write reprogrammable memory and has data retention of 10 years. Anti-collision features allow simultaneous read/write access of more than 30 labels per second.

CAPACITIVE COUPLING

Another "semiconductor name" that is present in the RFID market at the systems level, not the silicon level is Motorola, through its Indala subsidiary. Motorola has recently been involved in a development programme with Temic Semiconductors (part of Atmel) with Temic supplying the silicon for a new generation of smart label products in Motorola's BiStatix line. These tags are different from most others in the industry in that they rely on electric fields rather than magnetic, and the coupling is capacitive rather than inductive. The "antenna" is therefore one or two conductive pads - capacitor plates - rather than a coil and, in this latest development, the plates can be printed by any regular printing process, of conductive ink. The chip is then attached by conductive adhesive and a complete tag can be incorporated into conventional paper or card packaging. The wafer is lapped down until chips are only a few hundred microns thick. Temic CEO Frank Heinricht says that this technology makes viable smart labels that can combine the functions of price tag, anti-theft measure and product authentication, for products in the $10 to $20 value range. The tag is also completely disposable with minimal environmental impact, consisting of only a chip (practically inert), paper and ink. The chip has a similar feature set to a product already in Temic's range of chips and tag modules, the TK5552. For 125 kHz operation, the 5552 is a read/write tag a moulded package 12 × 5.8 × 3mm containing the tag chip, antenna coil and tuning capacitor, that has a 992-bit EEPROM programmable in 31 blocks of 32 bits. A block can be written and verified in under 50 msec. Other chips and tags in the Temic range include features such as encryption; the company has focussed its efforts at 125 kHz but has 13.56 MHz products in development.

An existing supplier of chips and tags, Silway has recently added a subcontracting service for design of transponder modules; as Product Marketing Manager Christophe Durouge puts it, "The OEM tag is to the transponder chip what the plastic package is to the IC." Silway will offer a service that will mount die from all of the major foundries of RFID silicon. The company already has SILsmart, a technology platform that assists with chip design for RFID, and incorporates IP in all of the company's areas of expertise, including RF interfaces, protocol management, peripheral interfaces and firmware.

Several of Silway's range of tags and tag modules (mounted tag plus antenna coil, ready for encapsulation in OEM format) maintain compatibility with tag chips from EM Marin in Switzerland. With its background in low power systems, EM-M supplies chips alone, rather than complete tags or modules. The H4000 series are laser-programmed read-only devices that operate at 125 kHz or 13.56 MHz, with options for memory size and anti-collision protocol. V4000 series devices are read/write with the option of an on-chip encryption algorithm (the V4070) in which a 96-bit secret key is held in an EEPROM that cannot be read once programmed, although the programming can be done via the air interface. A further option is an OTP feature, whereby the EEPROM content can be made permanent. EMM also makes a (powered) transceiver chip for use with the same systems.

One of the longest established companies in the RFID is Texas Instruments with its TIRIS products. TI is unusual in that its RFID business is vertically integrated, from silicon through to complete systems, although it does not sell the silicon alone. TI's established 134.2 kHz tags come in a variety of physical formats and provide 64-bit read-only and 80-bit read/write data streams. The most recent addition to the range takes the company into 13.56 MHz technology with a new series of Tag-it smart label inlays. These are rectangular inlays on foil carriers containing the transponder chip and a multi-turn antenna around the periphery. They are, says TI, designed for industries that need an easy-to-integrate, cost-effective, consumable RFID solution, being re-programmable, flexible and capable of being read simultaneously by fixed-position readers or handheld scanners. With a maximum thickness of 0.36mm, the inlay can be laminated between layers of paper, film or plastic. Three models measure 45 × 45 mm, 45 × 76 mm, and the new rectangular, miniature inlay at 22.5 × 38 mm. Looking to develop ID products in a new frequency band, TI has recently joined with SCS Corporation to design a UHF (868/915 MHz) passive tag technology: SCS makes the Dura-label 2.45GHz technology tag, with anti-collision tag protocol and long passive tag read range. With a frequency range between the two companies' areas of expertise, the intention is to capitalise on the strengths of both.

With products that conform to the ISO standard 15693 (see sidebar, "ISO is go") Inside Technologies manufactures chip and tag products for 13.56 MHz read/write operation, in memory sizes of 512 bits or 2kbits, with the option of 32-bit encryption. Anti-collision protocols allow over 30 tags per second to be read. French-based Inside also makes corresponding reader chips, and claims to be the only semiconductor company to focus only on the RFID market.

FLEXIBLE SILICON

Work on airline baggage tags has been carried out at the Berlin-based Fraunhofer Institute, in connection with its on-going development of advanced chip packaging techniques. The Institute is working on the "communicating price tag", and is aiming to have tags that are as thin and flexible as a paper label. The Institute also has a strong thread of work in progress in green, totally recyclable electronics, and one direction of its work - some of which has been carried out in conjunction with Philips - is towards completely plastic structures, with ICs built from conductive polymers rather than silicon. More immediately realisable is its work mounting transponder chips on to flexible polyester substrates, using conductive adhesive to mount and connect them. Prototypes of airline baggage tags have been produced, in the conventional wrap-round, self-adhesive format, with integral stamped foil antennae bound into the polyester strip. Fraunhofer's approach to the need for a flexible and rugged assembly is to make the silicon wafer extremely thin. The active, diffused layers in the IC extend only a very short distance into the wafer; thinned down to only tens of microns thick, the silicon wafer retains all its functionality but becomes flexible (and nearly transparent) - this thinning is achieved by a process that is first mechanical, then chemical. The Institute's Mathias Klein sees the technology as being useful in labels, smart cards, in vertically stacked chip structures, and in "chip in paper" applications.

FOR MORE INFORMATION...

For more information on products such as those discussed in this article, enter the appropriate numbers at www.edn-info.com. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN Europe*.

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The companies discussed in this article have limited by space to a representative selection of those involved in chip manufacture for RFID. There are very many next-tier companies involved in tag, module and system integration. A useful starting point for information on these companies is; www.execpc.com/~jimeagle/rfidweb.htm