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Conventional PCB

MAGICSTRAP®
- Standard SMT component
- read and write data
- UHF RFID: communication ranges from a few mm up to 10m

Smart PCB with RFID tag function

Batteryless RF-Technology:
Access information inside the product through layers of package
Process Integration = Value Creation

The smart PCB becomes Backbone of the Value Chain
The MAGICSTRAP® enables production tracking, asset tracking, service tracking and counterfeiting prevention at the PCB level.

With today’s sophisticated supply chain, tracking product has become an important part of each company’s responsibility. The ability to track a piece of equipment from the production process through the distribution channel to the end user with accuracy has become easier with the use of RFID.

Murata’s MAGICSTRAP® is the latest in UHF RFID chip development, designed to be placed on the printed circuit board (PCB). The integrated module eliminates many of the frustrations previously encountered by design engineers looking to incorporate RFID into their project.

By following some basic and simple guidelines, the antenna is designed into the PCB’s ground plane. This represents a permanent and cost effective antenna solution. Placement of MAGICSTRAP® is done using any commercial pick and place equipment. Once mounted, information can be stored and retrieved on MAGICSTRAP® using any EPC global compatible UHF Reader/Writer.

Key Features:

- EPC Global Class 1 Gen2 / ISO 18000-6C compatible
  - UHF frequencies (860 – 960MHz)
- Antennas impedance matching function integrated into MAGICSTRAP®
- Up to 4–7 meter read range is possible
- Antenna patterns/guidelines are available for various sizes of printed circuit boards to meet a wide range of applications
- Utilizes ground as antenna – no additional cost
- Memory Capacity – 512 bits ~ 3,3 Kbits
- Compact Size (3.2 x 1.6 x 0.55 or 2,5 x 2,0 x 0,55mm)
- RoHS Compliant
I²C MAGICSTRAP®
UHF RFID - Create and Protect Value

**Key Features:**
- I²C Serial Interface to Microcontroller or CPU
- 3,328-bit user memory
- Dual frontend architecture
- Best-in-class RF sensitivity
- Up to 160-bit EPC
- 96-bit TID, including 48-bit serial number
- EPCglobal 1.2.0 standard
- Switchable RF and I²C interfaces
- Digital switch
- RF-to-I²C bridge mode (handshake)
- Interrupt output

**Applications**
- Product Configuration
- Device customization
- Firmware downloads
- Return management
- Counterfeit protection and authentication
- Production information
- Theft protection and deterrence
- Production automation
- Shelf-life calculation
- Sensor applications
- Electronic shelf labels
UHF RFID on PCB: Smart Value Creation in the Electronics Industry

The electronics industry is constantly searching for an auto ID solution that can provide additional functions beyond simple traceability. Ideally such a technology could become the backbone for a product lifecycle management (PLM). Optical identification approaches including bar codes or data matrices cannot be used because these information carriers become inaccessible after the PCB has been mounted in its enclosure. Repeated examinations in the RFID segment failed to yield a flexible multi-purpose solution so far. This situation has drastically changed now.

Initial examinations set their focus on RFID technologies using LF and HF frequency bands. These seemed basically suitable because passive solutions (no batteries required for functionality) are available and device enclosures and outer packages do not create an obstacle because of the radio-based nature of this approach. However, these technologies use relatively low frequencies (LF: 125kHz; HF: 13.56 MHz) with corresponding long wavelengths. Therefore, the tags require relatively large antennas in order to achieve read distances of more than a few centimeters.

The UHF band thus remains the only choice for passive RFID approaches. Communication distances of more than 5 meters are supported by small antennas on the tag side. This range enables applications over the entire value-creation chain from the ‘Beginning of Life’ to the ‘End of Life’ of a product (see fig. 1). As the following discussion reveals, this even includes the product development process. Based on a global standard (ISO 18000-6C and EPC Global C1G2), UHF RFID technology can be seamlessly used even if the manufacturing site should be located in the Far East and the finished or semi-finished products would be shipped to the U.S. or Europe. Contrary to optical ID approaches, current RFID technology even supports the in-situ modification of the tracking data, as a rewritable memory is included in the RFID ICs. Finally, the UHF standard also allows bulk scanning, resulting in today’s massive use of this technology in the fashion industry and in logistics processes. It should be noted that bulk scanning of electronics devices still is a challenge because of the high metal content of many of those devices. Nonetheless, Siemens was able to prove in real-world installations that this problem can be solved in electronic products. [1]

The introduction of RFID technology is often hindered by system integration issues which are seen as a major issue and have led to the failure of RFID projects. [2]

The following paragraphs will describe that these two obstacles, technological issues and system integration issues, have been cleared now. The basic technical solution which is 100% based on standard production processes in the electronics industry will be presented. This is followed by the introduction of the ‘RFID Value Creators in Electronics’ consortium which supports the proliferation of these solutions. The consortium solves the integration problem in advance by offering complete and scalable system solutions instead of having the user resort to a tedious and costly approach. As an
industry first, the flexible solution offered by the partners of the consortium enables the UHF RFID approach to be used from the early stages of the product development process. It can then be utilized as a basis for value creation throughout the entire downstream chain. This might even include customer services based on the RFID functionality. A couple of times already, the consortium successfully demonstrated that all participants of the value chain can benefit from this useful approach. The RFID implementation at Schneider Electric provides a good example. [3]

Current members of the consortium include Murata, offering the Magicstrap® as an optimum solution for using the PCB as an RFID tag. Brooks operates as hardware system integrator, who will put the RFID solution in place at the customer. Another member is Kathrein. As a provider of various reader antenna solutions with different read ranges (e. g. the LORA offering outstanding selectivity), Kathrein enables the RFID enabled PCB to be used as a tag in the entire value-creation chain. The company Enso Detego is providing the necessary software solutions in order to connect the RFID hardware to the existing IT infrastructure, the so-called middleware. The consortium member Beta LAYOUT provides an approach for embedding Magicstrap® into prototypes, enabling the RFID technology to be used in the product development stage already. In addition, alpha-board is a company offering layout support to customers with special requirements regarding the tag antenna solution on the PCB side.

In the Beginning there was the PCB

As the basic element of any RFID System, the RFID tag carries a unique ID, which will reliably identify the product, as well as supplementary information in a rewritable user memory. Unauthorized use can be prohibited by an access password. Considering the size and complexity of an electronic system, the question is where the value of
Where is the product located and where the tag should thus be mounted? In our context, this means, at which part of the product the RFID function should be placed, so that it can be used across the entire value-creation chain? The printed circuit board (PCB) included in the devices is an obvious candidate for the location of the RFID function, because it carries the functionality and marks the beginning of the value-creation process. Theoretically, the PCB is also ideally suited for RFID, because it already provides a large metal plane (the so-called ground plane) embedded into it. In principle, this metal layer could be considered as an antenna for the RFID function. Depending on the specific circuit, this ground plane can cover most or only part of the PCB. It may be continuous or bear wholes in itself. Therefore, the electrical characteristics of ground planes exhibit large variations impeding or even precluding their use in the past.

This is where Murata’s Magicstrap® comes into play. In the Magicstrap® product, Murata combines a conventional UHF RFID IC (currently the G2XM / XL by NXP) with a ceramic multi-layer structure carrying an adaptive matching circuit implemented in three dimensions on the different ceramic layers (fig. 2). The resulting electronic component can be mounted onto the PCB using industry-standard surface-mount technology. The integrated matching circuit enables the ground plane of the PCB to be used as an antenna. This means, the Magicstrap® provides a solution to potentially turn any PCB into a functioning UHF RFID tag. And this, by simply mounting one more component in the standard production process. Furthermore, it provides suf-
icient flexibility to yield a functioning tag even under the conditions outlined above. Only the range will vary. Fig. 3 illustrates the minimum PCB area required by this approach. An area of 0.25cm² is already enough for a read range of more than 50cm. For a maximum scalability and flexibility, Murata provides four different layouts to connect the Magicstrap® resulting in different read distances for a given PCB size (fig. 3). The length of the longest PCB edge is another factor influencing the communication distance. Fig. 4 illustrates how the read range depends on this parameter. As the most flexible layout, type 3 offers the optimum tradeoff between range and occupied PCB area. With such a scalable and flexible solution, it is almost always possible to turn a PCB into an RFID tag. Only the suitable layout for contacting the ground plane must be selected. Interested customers can obtain the layout data required for this task from Murata free of charge. A study conducted by Kathrein confirms this flexibility and also demonstrates that the expected result can be excellently simulated in advance. [4] This is even the case for panel manufacturing where multiple PCB tags co-exist side by side. The study also reveals that further optimization of the read range can be achieved if necessary using suitable simulation software, by modifying a standard layout or by creating a custom tag antenna design. Alpha-board is a company offering these layout optimizations as a service.

With this solution, the value carrier, that means the PCB itself will also carry the ID information. This results in a most efficient combination of RFID technology and the product itself based on the industry’s prevailing manufacturing processes. By turning the product itself into a ‘smart object’ right at the beginning of the creation process, this feature is available throughout the following steps in the value chain without any media disruption.

To ensure reliable functionality, RFID should always be treated as a system-level solution. Instead of being focused on the tag alone, any consideration should also take the read/write device into account. In order to address as many stages of the value-creation chain as possible, the tag itself should basically enable a long reading range, while the adoption to a specifically required read range in a process step should be done through the selection of an adequate reader solution. This involves selection of the type of reader antenna and the power with which the reader is operated. In a manufacturing environment it is often necessary to address individual PCBs, which raises the problem of unwanted reads, if UHF RFID technology is used. As mentioned above, read distances of several meters can easily be achieved if Magicstrap® technology is used to turn PCBs into tags. Consequently, a reader whose antenna and transmit power are designed for maximum reach will address all tags within its range. This may be an advantage in logistics applications where it is often necessary to scan many items simultaneously, but it clearly is a drawback in an electronic manufacturing environment which may require an error-free identification of individual boards in order to create a reliable traceability system. Most often, PCBs are manufactured in a panel consisting of multiple PCBs running through the assembly line (see fig. 6). When placing the components on the board, it may be necessary to exactly identify the PCB in the panel to which the components are mounted at that moment.

This is where Kathrein’s antenna portfolio in combination with the readers and the integration experience of Brooks comes into play. In addition to antennas for medium-range applications (i.e. intra-logistics) or long read distances (which may be required in logistics applications or for bulk scanning), Kathrein also provides the LORA antenna for individually addressing UHF tags which are very close to each other (see fig. 5). Further optimization can be achieved using software approaches in order to filter unwanted data from the necessary. Nonetheless, a suitable antenna and the consideration of the actual environment is the basis for a reliable system. The years of experience of Brooks in realizing RFID based systems in production environments, ensure that such a reliable system can be achieved within a short time frame and based
on standard elements. This functional principle can be evaluated by prospective customers at Kathrein’s RFID lab and demonstration center in Amerang, less than an hour’s drive south of Munich. A small demo PCB assembly line offers the opportunity to demonstrate the functionality and reliability of this solution under real-world conditions (see fig. 6).

Therefore, nothing stands in the way of using this technology in electronics production environments anymore. Evidentially, considering the system character of RFID in combination with suitable tag and reader technology will lead to success. This means that the PCB turned into an RFID tag can be used across the entire value-creation chain regardless of the conflicting requirements in the various segments.

**Back to the Roots**

Before entering production, however, it is necessary to take a step back and look at the product development stage which represents another process. Today, many companies either have no manufacturing operations at all or have their manufacturing operating running at its maximum capacity or optimized for high throughput. This has resulted in a demand for prototype manufacturing services. Beta LAYOUT may have different software versions or similar components with different electrical characteristics. RFID is an ideal solution for handling this kind of prototypes.

The highly innovative solution offered by Beta LAYOUT utilizes another feature of the Magicstrap® product. The matching circuit included in its multi-layer structure also works as an antenna. As a consequence, the Magicstrap® alone can be used as a complete UHF tag. The only tradeoff is that the read distance will be degraded because of the tag antenna’s minimized dimensions. Nonetheless, read distances of several millimeters can be achieved without any external antenna. Beta LAYOUT developed a cost efficient solution for embedding the Magicstrap® device into PCBs. ‘Embedding’ in this context means that the Murata module is completely removed from the surface of the board and integrated into the PCB structure. Apart from prototype management, this approach can also be used to implement a hidden counterfeit protection scheme. Beta LAYOUT offers its customers to deliver prototype PCBs with integrated RFID functionality if desired. Customers thus can already make evaluations of the RFID functionality in this early stage of the product-creation process.
This specific use case can be supported using standard reader technology. The only exception is that a loop antenna must be connected to the reader for successful communication with the Magicstrap®. Beta LAYOUT provides a low-cost solution for this. If the solution must comply with industrial requirements, an alternative would be to use Kathrein’s LORA antenna which also couples with the Magicstrap® without a booster antenna.

RFID technology can thus be profitably used in the product development. Applications include prototype management and technology evaluation. A special case is counterfeit protection if the embedded approach is also used in volume production. But this solution can as well be used for traceability purposes.

In addition to the development of new products, where the layout can be adopted accordingly, a frequent question is how existing PCBs with a fixed design can be enhanced by RFID functionality. Magicstrap® is a candidate for this if one of the antenna designs is added during a redesign. Beta LAYOUT provides a helpful intermediate solution for users who do not have any simulation software or just want to carry out some initial practical tests. The solution consists of mini PCBs which carry one of the three smallest Magicstrap® layouts and can be mounted on the existing PCB for initial functional tests.

Last but not least, as a requirement coming out of the R&D departments Beta LAYOUT offers a complete UHF RFID starter kit. This low cost kit dedicated to the needs of development engineers contains everything needed in order to evaluate UHF RFID technology, even the necessary software to quickly create useful applications based on the RFID enhanced ‘smart’ PCB.

The RFID solution described here thus can be used in the electronics industry to generate value right from the very beginning. Data generated by prototype identification at this early stage will thus be reliably available during the entire product-development phase and beyond.

**Hard Facts Created by Software**

The usefulness of an RFID solution largely depends on adequate software to efficiently process the ID data. In most cases an established IT infrastructure will be available in the relevant processes. The integration of the tag/reader solution described above should occur as quickly and seamlessly as possible. A special type of applications, often referred to as “middleware”, has been created for this purpose, ensuring that the right data will be routed from the tags to the readers and that the data will then be forwarded to the relevant databases and event monitors. Physical aspects and an understanding of the process play an important part in this context. Tags not relevant for a process will frequently be within the range of a reader used in that process. In addition to the optimum combination of tag and reader parameters, this problem can also be solved or at least mitigated by intelligent software algorithms. Enso Detego has spent huge efforts in creating such software. As an alternative to reinventing the wheel again and again, excellent software solutions which have been enhanced by algorithms over the years are provided by Enso Detego. Suitable middleware can help to reduce the costs on the way from the first feasibility study to the introduction into current processes. But also complete stand alone solutions including server based services are available form this consortium member.

**This Is All Just the Beginning**

It has been demonstrated that a flexible, scalable system solution is now available for using RFID in electronic products. As a unique feature, solutions covering the entire value-creation chain are available or in development. Applications including the one at Schneider Electric demonstrate that this approach provides significant advantages even for very large corporations. Apart from traceability and process control applications, the readability of information even through the device enclosure or its outer pack-
Aging enables applications covering the whole process chain. Counterfeit protection is among the most urgent applications, and there already are practical implementations of this concept. Of course, no details can be disclosed due to the sensitive nature of this issue.

The value of RFID extends to the end of life of a product, and recycling represents this stage of the value-creation chain. On the one hand, the importance of this issue results from stricter regulations (e. g. EU directive 2002/96/EC). The EU has recognized that RFID is a good approach for systematic electronic product recycling. Several projects are already being publicly funded in this context. On the other hand, the cost trends of the commodity markets increasingly mandate an efficient approach for recycling valuable materials.

A company considering RFID use over the entire value-creation chain (see fig. 1) will also benefit from a very straightforward ROI calculation because any costs will pay off in a short timeframe due to various advantages although these may be identified only after the introduction of this approach. As mentioned above, using the PCB as a carrier for the RFID function is the starting point resulting in maximum benefit at minimum investment.

The consortium “RFID Value Creators” has assumed the task to make this RFID technology available to all interested parties and to continuously expand the range of application. The members have already entered into a dialog with various industry associations and are available at any time for further discussions. Furthermore, additional companies willing to co-operate in the introduction of RFID into the entire chain or specific segments are invited for dialog and co-operation.

A special problem becomes apparent in the disruption that can occur in the value-creation chain of this industry as a result of using so-called Electronic Manufacturing Services (EMS) for PCB manufacturing and assembly. In this context, the consortium is inviting the participating companies to start a ‘constructive dialog’ with the goal of jointly creating cost-sharing models.

Quite often, it turns out that the introduction of RFID technology by companies is frequently hindered by lacking knowledge of existing solutions. The members will therefore increasingly give lectures and provide information material on this subject at relevant events.

The author thanks all people who have actively contributed to this project with much dedication and openness, helping it to reach its current state and keep growing. The consortium members also welcome anybody willing to join the project in the future.

Sources:
(2) http://www.stiftung-industrieforschung.de/images/stories/dokumente/forschung/rfid/Braschuere_KMU.pdf
(5) http://www.eaims-project.com/
(S. 3, 2.1. The social contribution of RFID)
Beta LAYOUT was established as a PCB supplier in 1989. In 1994, Arne Hofmann had the brilliant idea of populating one panel with many different PCB orders - so that the tooling costs of this panel could be shared between the various PCB designers. This gave rise to a huge reduction in the costs normally associated with prototype manufacturing.

More than 15 years later, with over 170 employees and over 28,000 customers, this idea has been so successful that the Beta Group is now one of the largest PCB suppliers in Europe.

Beta LAYOUT customers range from small one-man companies and electronics hobbyists to the research & development departments of some of the largest and most recognizable companies in the world. Today, Beta LAYOUT not only delivers PCB prototypes and small series but also laser-cut SMD stencils, Front Panels and SMD soldering solutions and offers a wide range of other services from its bases in Germany, Ireland and South Africa.

You, our customers, have ensured that what was once just an idea has now become a thriving, successful business. For this we would like to say a big thank you!

More information about Beta LAYOUT GmbH and their products and solutions can be found at:

www.beta-layout.com
Brooks Automation

**Brooks Automation GmbH** is a global supplier of automation solutions headquartered in the US state of Massachusetts. Founded in 1978, Brooks has approximately 2400 employees worldwide, with locations in North America, Asia and Europe.

Brooks is listed on the NASDAQ stock exchange under the ticker symbol BRKS. Its customer community includes all renowned semiconductor manufacturers and other companies in industrial branches where production processes with similarly exacting standards have to be handled.

Located in Germany, the company’s RFID Division provides premium RFID system solutions for procedural improvement in logistic, manufacturing and quality control operations.

Container management, maintenance scheduling, direction of material flows, access control, and tracking of quantities and contents – all these representing but a small fraction of a whole range of functionalities which RFID can make much more simple and streamlined.

**More information** about Brooks Automation and their products and solutions can be found at:

www.brooks-rfid.com
Enso Detego

Enso Detego provides intelligent RFID solutions, expert technology consulting and successful project implementation based on proven software products.

The product detego® SUITE ensures rapid and effective implementation of RFID projects. Standardized processes in the areas of production, distribution and retail are supported by high-quality and market-proven RFID solution modules. The flexibility of scalable modules allows the adjustment to strategic requirements and the integration with enterprise business processes.

Visibility in the supply chain, efficient replenishment based on maximum inventory accuracy, acceleration and preventing of mistakes in stock taking processes, anti-theft and anti-counterfeiting are some examples of themes Enso Detego works on. As developer of a powerful RFID Middleware and supported solutions modules the company aims at creating added value for its customers and partners.

The products and services address the industries fashion, automotive, food and electronics. Especially in the fashion segment a leading market position could be achieved.

More information about Enso Detego and the detego® solution modules can be found at:

www.enso-detego.com