CONFERINȚA NAȚIONALA A ENERGIEI – CNE 2004
Neptun, 13-17 iunie 2004

Cod lucrare: S5p-05-en

MODERN TRANSPONDER BASED SYSTEM FOR MATERIAL CONTROL

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1. Transponders in identification and material control systems.

Transponders were originally complex electronic circuits that were attached to some items whose position or presence was to be determined. In operation one can generally say that there are two different types of transponders: passive and active transponders [1]. Active transponders need a battery to supply the energy to operate. A passive transponder doesn’t need an own power supply circuit and it gets the energy for functioning from the reader's energising field, which is mainly an electromagnetic field. This paper presents a modern system passive transponder based for material control.

A passive transponder can be considered like a memory. This memory can be red by a special reader, using electromagnetic field. The whole communication between reader and transponder is a contact less one. Modern transponders can also be written or updated with data sent by enhanced reader using the same electromagnetic field. The data capacity for transponder’s memory is usually between 64 bits and 4 kbits. An important parameter for reader-transponder communication is the range: the distance between reader and transponder in which a communication via electromagnetic field can be done. There is a range for reading operation and a smaller range for writing. The reading range is usually 1-2 m. Few producers announced already a 10-12 m range, using 900 kHz (or above) transponders and high gain reader antenna. In all passive transponder based systems, the main factor for this range is the power of reader and antenna dimensions.

In order to extract the energy for functioning from the reader’s electromagnetic field, the transponder is using a parallel resonant circuit. This electric circuit is composed from an external inductance and an internal capacitance of transponder (the input equivalent capacitor). The resonant frequency of this circuit has to be the same with the reader’s frequency. The practical external inductance consists in a number of copper turns. The electromagnetic field issued by the reader is passing through this coil. Both electromagnetic components, electric and magnetic, could be used by transponder. From this point of view, we can find magnetic coupled transponders and electric coupled transponders. The magnetic coupled transponders are the most common transponders available today [1]. Generally they are operating at frequencies typically in the order of 125 kHz or 134 kHz and the range is 1-2 cm. Many applications are already available on the market, including application in tagging animals, electronic automobile key identification and factory automation. Electric field coupled transponders [1] generally provide vastly increased ranges over their magnetic counterparts. Rather than being limited to the ranges of the lines of force emitting from a magnetic field generator, they use the electric field propagation properties of radio communication to convey energy and data from the reader to the transponder and to send back the data stored. The main advantage of the electric coupled transponders is the range that is usually 1-2 m. The applications are available on retail, shipping container and railcar tracking, animal tracking, vehicle access and control, personnel access, production and material control, etc [2,3].

The read/write operations between reader and transponder are via electromagnetic field. The transponder is replying to an interrogation request received from reader, either by returning some data from the transponder such as an identity code or the value of a measurement or returning the original properties of the signal received with virtually zero time delay, thereby allowing ranging measurements based on time movement. As the interrogation signal is generally very powerful, and the returned signal is relatively weak, the returned signal would be swamped in the presence of the interrogation signal. In order to accomplish the communication, the transponder will move some properties of the returned signal from that of the interrogation signal so that both could be detected simultaneously without the one swamping the other. The most common property to change is the transmission frequency meaning that the transponder might receive the interrogation at one frequency and respond on another frequency that is separated sufficiently with regard to frequency so that both may be detected simultaneously.

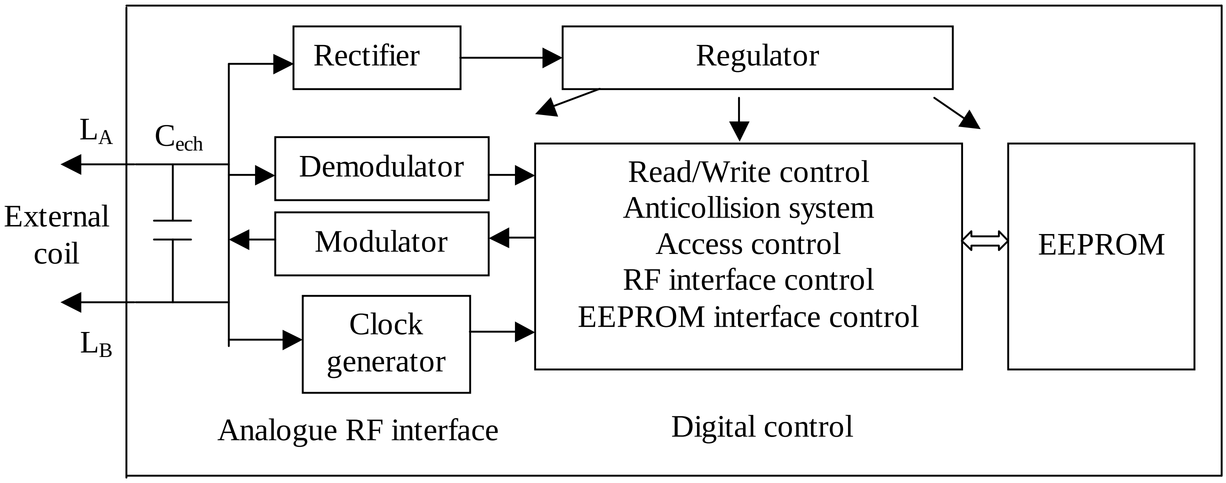
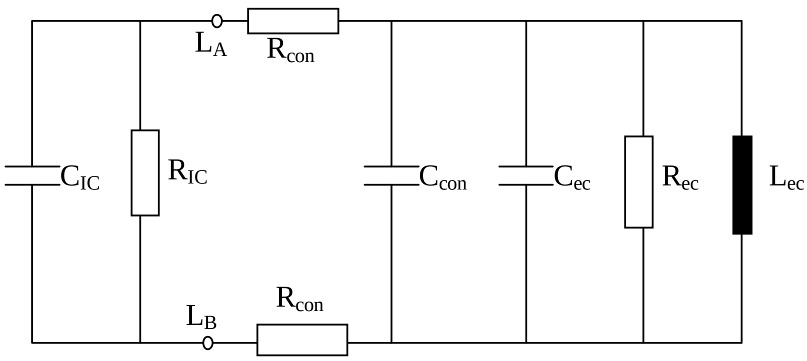


Figure 1. Transponder – block diagram

The block diagram in figure 1 shows the basic building blocks of the transponder. The equivalent input circuit for transponder is depicted in figure 2. The rectifier is using the output signal from parallel resonant circuit (external coil connected at L_A, L_B and equivalent internal capacitor C_{ech}). The rectified signal is stabilized and it is used to supply the internal electronic circuits. A carrier frequency f_o and a amplitude modulation are used for data communication between reader and transponder. The modulation index is 10% or 100%. The demodulator unit extracts data sent by reader. A sub-carrier frequency ($f_o/32$ or $f_o/28$) and the same amplitude modulation method are used to sent data from transponder to the reader. The clock used both by modulator and demodulator is obtained from the input signal using a special oscillator (PLL circuit



C_{IC} – equivalent input capacitance

R_{IC} – equivalent input resistance

R_{con}/C_{con} – equivalent contact resistence/capacitance

$L_{ec}/R_{ec}/C_{ec}$ – inductance/ resistance/capacitance for external coil

Figure 2. Equivalent input circuit for transponder

based). The digital control unit is managing read/write functions, EEPROM interface and RF interface. An anticollision protocol is implemented also. This protocol helps the reader to identify more tags situated simultaneously in the reader range.

2. The necessity to introduce modern material control system.

The introduction of the ISO 9000 standard in production and services fields implies a radical change in the company quality system. To compete with similar companies is possible today only with certified ISO quality system. One of the procedures in ISO quality systems is "Product ID and traceability". The purposes of this procedure are:

- to identify a product from the receipt of material through product delivery;
- to maintain historical records of the item;
- to be able to trace assemblies and selected subassemblies;
- to define the methods which must be used to provide product identification and traceability integrity by means of labelling, bar coding, etc.;
- to provide procedures for identifying and tracking major components, modules, test results and final product during all stages of production and delivery.

Another procedure in the ISO quality system, "Control of nonconforming products" is requesting to rich next purposes:

- to evaluate defective products and products of questionable integrity;
- to evaluate the cause of defects and rework the part where possible;
- to create a permanent solution that prevents recurrence of problems;

and the „Servicing" procedure is looking to control the disposition of material returned to the company from customers and dealers.

To create a material control system according with all these procedures is not easy. In this paper is described a transponder based system that can create the support to implement all these quality procedures and to help testing, material transport, packaging and incoming quality control departments for a factory with complex final products. The system will identify all important materials and component parts of the final product in order to identify and control the suppliers, incoming quality approvals and to trace the material in all production departments.

There are already implemented few identification systems (ID systems) bare-code based, but this kind of systems can control one ID number for each part or material but no more data can be stored on the label. Using a passive transponder (with memory included) attached on items, we can control both material, components, subassemblies and final products in warehouses, production, servicing, the distribution process until final customer, including the return for failed or defective products.

3. The material identification system

The block diagram of the identification system transponder based is depicted in figure 3. In this figure we can remark all three main parts of the system:

- the PC unit;
- the reader
- the tag.

The reader contains a control unit microcontroller based, a RF block for bi-directional communication with transponders via electromagnetic field, a modulator/demodulator block for coding/decoding data and a RF antenna circuit. The power supply for all these internal circuits can be obtained both from main power (220V) and accumulators (12V).

The tag (the transponder and own antenna - label coil) will be attached to the item during incoming material process. Both elements (transponder and antenna) will be protected against durst, scratches or improper manipulation by lamination or lacquer. A self-adhesive support for transponder and antenna, in order to attach them to the received item will be used. This tag will remain attached to the item permanently.

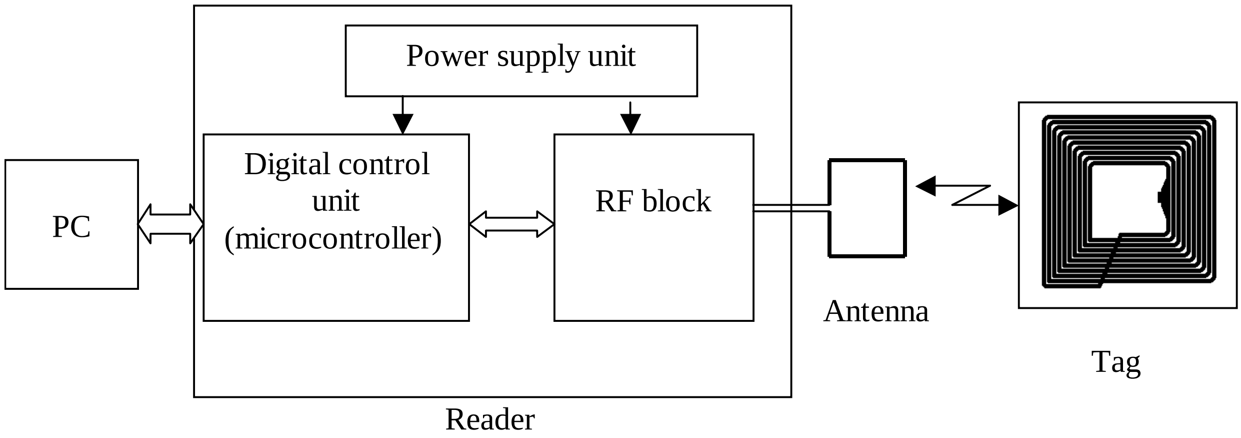


Figure 3. Block diagram for identification system

The PC contains a database with essential information about all received items, their history and movements inside the company. In order to update this database, the reader contains a serial communication interface according with RS 232 standard or a wireless connection, using a radio modem (2,4 GHz free license). Thus, the material control manager can identify and trace all registered materials. Stationary and mobile readers permanently update the database with all changes in material status and their movements. The most important data stored in database are:

- identification code (ID) for received materials and subassemblies;
- Item description;
- Supplier;
- Incoming data (into Incoming Warehouse);
- Outgoing data (from Finish Goods Warehouse);
- Actual position in production flow
- Incoming Quality Control status
- Item destination (or transport line)

A specific description is recorded for finish goods. Each final product will have an unique identification code, description and all ID codes for material and components included in the final product, delivery date from production, delivery date to customer, etc. For returned product, beside all above data, the database will add: return date, ID code for material replacement, delivery date back to customer.

The material control manager can also program the destination for all material stating with incoming material warehouse. In this way it's possible to optimize the internal transport and material purchasing for all departments.

All data described above are stored both in the memory tag and the database from PC. In order to reduce the total cost of the system, the tag has to be carefully designed. For this system we proposed a passive transponder Philips SLI [4], according with ISO 15693 – the standard for RFID specifications. The transponder is working on 13,56 MHz, contains 896 bits EEPROM (28x32 blocks) available for read/write operations and one 64 bits unique identifier, programmed during production process according with ISO 15693 (it cannot be changed afterwards). For this transponder and application, a label antenna is the best solution. This antenna consists in 9 copper turns printed on a permanent general adhesive, top coated with a protective film. The resonant frequency for the equivalent input circuit (figure 2) has to be equal with operating frequency:

$$f_{res} = \frac{1}{2\pi\sqrt{LC_t}}, \quad where \quad C_t = C_{IC} + C_{con} + C_{ec}, \qquad f_{res} = 13{,}54MHz \qquad (1)$$

In relation (1) we approximated $R_{con} = 0$. According with practical tests and data book, the capacitance values from figure 2 are:

$$C_{IC} = 25.5 \text{ pF}, \; C_{con} = 1 \text{ pF} \;\; C_{ec} = 2 \text{ pF} \qquad (2)$$

Using relations (1) and (2), we obtained a necessary inductance for external coil: L = 4,83 μF. Many shapes can be used for this coil. We have chosen a 9 turns rectangular shape, like in figure 3. According with [5], the planar inductance for a rectangular shape can be calculated with:

$$L = L_0 + M_+ - M_- \tag{3}$$

where L_0 is total inductance, M_+ is the sum of positive mutual inductances and M- is the sum of negative mutual inductances. The mutual inductance is the inductance that is resulted from the magnetic fields produced by adjacent conductors. The mutual inductance is positive when the directions of current on conductors are in the same direction and negative when the directions of currents are opposite directions. The mutual inductance between two parallel conductors is a function of the length and of the geometric mean distance between them.

According with [5] L_0 can be calculated with:

$$L_0 = 2l\{\ln\frac{2l}{w+t} + 0{,}50049 + \frac{w+t}{3l}\} \qquad (nH) \tag{4}$$

where *l* is the length in inches, *t* is the thickness in inches and *w* is the width in inches. We designed the coil with *w* = 0,6 mm, 0,1 mm inter-turns distance and 50 μm thickness. The conductor length is increasing from 26 mm (internal turn) to 38 mm (external turn), with a 1,5 mm increment. The transponder coil size is 38x38 mm and the adhesive support size is 48x48 mm.

The mutual inductance between the k segment and p segment is calculated according with [5] using the relation $M_{j,k} = M_{k+p} - M_{k-p}$ where:

$$M_{k+p} = 2l_{k+p}\ln\left\{\left(\frac{l_{k+p}}{d_{j,k}}\right) + \left[1 + \left(\frac{l_{k+p}}{d_{j,k}}\right)^2\right]^{1/2}\right\} - \left[1 + \left(\frac{d_{j,k}}{l_{k+p}}\right)^2\right]^{1/2} + \left(\frac{d_{j,k}}{l_{k+p}}\right) \tag{5}$$

where l_{k+p} is the sum between lenghts of k segment and p segment, d_{k+p} is the distance between their central axes. The M_{k-p} mutual inductance is similar calculated.

With relations (3), (4) and (5), the total inductance is L = 4,82 μF. The antenna and transponder attached on the adhesive substrate are presented in picture 4.

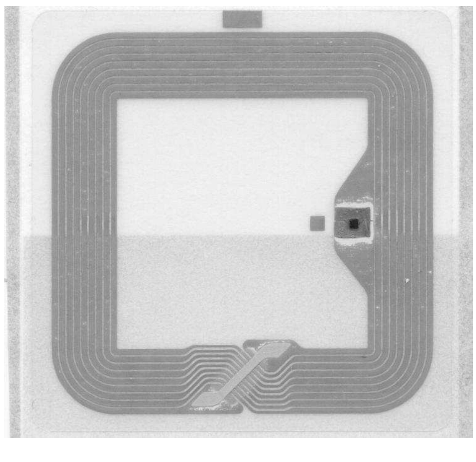


Figure 4. ID tag (transponder + antenna)

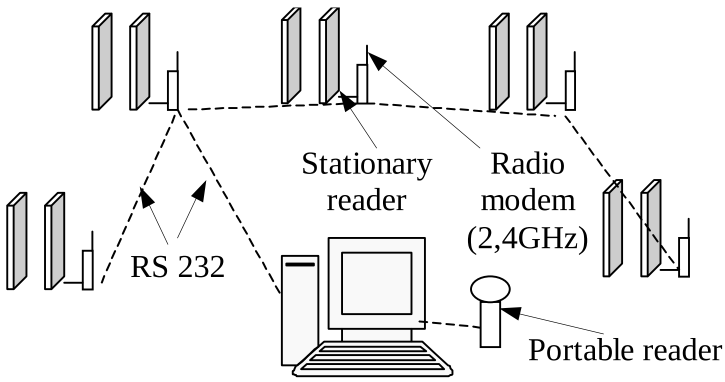


Figure 5. Material control and identification system

4. The system implementation

The block diagram for identification and material control system is presented in figure 5. In this block diagram, the connection between stationary readers and mobile (portable) readers can be done both via serial cable (according with RS 232 standard) and via a wireless connection (using a radio modem on 2,4 GHz license free, according with FCC part 15.427 certification). The portable readers will be used in Incoming quality control department, in production lines for quality control and in finish goods warehouses. The stationary readers will be placed on each department's gate to record data for each material movement.

In the incoming warehouse, the first step in the identification process is to attach the tag (transponder + antenna) to the material received. Each tag will have a unique identifier number that will be allocated in database to one received material. Examples presented in table 1 show basic information stored in tag's memory and database for a specific material received.

Table 1

Serial number	EEPROM
A25F78569426741F	Description: Video card Radeon
	Supplier: Flamingo
	Producer: ATI Technologies
	Incoming date: 20.12.2002
	Localization: Warehouse 1/...../..../.
	Outgoing date:
	Status: accepted/testing/rejected
A25F785678265540	Description: 128 MB memory card
	Supplier:: Flamingo
	Producer: IBM
	Incoming date: 20.12.2002
	Localization: Warehouse 1/...../..../.
	Outgoing date:
	Status: accepted/testing/rejected

For each transfer from incoming warehouse to production departments, for transfers between production departments and from production to finish goods warehouses, the stationary readers will record the transfer data to the tag's memory and will update accordingly the database from PC. In finish good warehouse, the final product will receive a new tag, with a new unique identification number and a specific recorded data in EEPROM. All material ID numbers included in the final product will be allocated to this new identification number. To record all these number, the final product will be red by a portable reader. This reader can read all ID codes for components and subassemblies included in the final product due to anticollision protocol implemented.

5. Conclusions

The material control and identification system implementation will take multiple advantages like:

- each final product will have a unique identification number that can be traced through final customer;
- all ID codes for final product's components will be stored in the final product tag's memory and will be available everywhere;
- the producer or the service department will get a modern system to trace the final products until final customer, in service or at distributors or even in own returned department;
- the system will offer an easier tool to get information about failed components and its supplier in order to improve the quality system;
- the system will offer a modern tool for material management, optimization of material transport in production and on-line production survey.

In conclusion, we consider that the proposed system is suitable for all companies that will introduce or will evolve their own quality system, especially the material control system.

6. Bibliography

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