Abstract

Electronic Service Chemnitz is a small company with 5 employees. Main business is the design, manufacturing and distribution of devices and equipment in the field of electronic alarm, monitoring and security systems. One important product in this area is the SEW1010 immobilizer system to be used in cars, lorries, motorbikes and motorboats with fuel or diesel engines.

The objective of the Application Experiment was to reach an extended market share for this product, and an essential improvement of the company’s competitive situation at all. Before starting the project, the immobilizer system was used only for retrofitting purposes. The application range should be extended to installations in new cars. In order to meet these objectives, a lot of technical features had to be implemented into the system. An additional difficulty was the existing standards in the automotive industry sector which had to be met.

The new product offers

- a higher reliability
- high safety against unauthorised use and theft
- improved technical features (e.g. control of different systems which are relevant for starting the car)
- extended temperature range

The only way to solve the problems was the introduction of MCM technology into the product and, going beyond the scope of the Application Experiment, into the daily business of Electronic Service. The necessary know-how was not available and was transferred within this project.

The manager and the staff have their origins more in the technical than the commercial area. That’s why the benefits offered by microelectronics were known. The main barrier that prevented to start such a project before was more a technical and know-how-oriented one than a psychological. The microelectronics experience was restricted to the design of conventional PCBs with discrete analogue or digital standard components. Within the Application Experiment the company learned to plan and manage MCM projects. Basic knowledge in MCM technology and design methodology was transferred. The company got knowledge in manufacturing technologies of MCMs using ceramic substrates as base materials and MCM test strategies as well. Within the immobilizer, the MCM is mainly used as AM demodulator, high selective filter and comparator. It contains about 122 components including 6 dices.

The immobilizer system will be installed in different car types, a modification of the system is therefore necessary. This was the reason to transfer also know-how in microcontroller technology and programming methodologies to Electronic Service.

The project was started in April 1997 and ran for 13 months, which was 3 months longer than planned. The reason were other unforeseen businesses of the company which prevented a continous work on the project.
The total costs of the AE were 75 kECU. Assuming a product life time of at least 5 years, the expected ROI for the FUSE investment will be about 1000%. This is, because the company was able now to open up the door for a real mass production with continously increasing sales figures. The resulting payback period will be about two years.

**Keywords:**
- MCM
- Atmel microcontroller
- Automotive Industry
- Immobilizer systems
- Identification systems
- Transponder
- Small company

**Signature**

| 6 | 0100 | 555 | 0410 | 5 | 3430 | 1 | 33 | D |
1. Company name and address

Electronic Service Chemnitz
Parkstraße 9a
09120 Chemnitz

2. Company size

Electronic Service Chemnitz is a selfstanding company owned by the manager Mr. Roland Schubert with an annual turnover of about 350k€.

The company has 4 full-time employees: one manager, one development engineer and two skilled workers for manufacturing.

Additional staff is employed for distribution and installation of the company’s products, e.g. the immobilizer systems. The manager and the development engineer were mainly involved in the Application Experiment.

3. Company business description

Electronic Service Chemnitz is a supplier of electronic alarm, monitoring and security systems for a wide range of applications starting from building sites, museums, car shops up to special solutions for public authorities, e.g. criminal investigation departments. The company develops, manufactures and installs such systems. The devices are assembled and tested in-house, the PCB manufacturing is outsourced.

One important business field is the manufacturing of immobilizer systems for cars, lorries, motorbikes and motorboats with fuel or diesel engines. The company is on the market with different devices. One main product is the immobilizer system SEW 1010 which is sold now for about five years.

The second main business is currently the development and manufacturing of sewerage inspection systems. This kind of business is also growing very fast. Many municipalities are going to introduce such systems to automate the annual inspections which were very time and cost consuming up to now.

Other products offered by Electronic Service Chemnitz are systems for fire prevention, image processing and radio picture communication as well as different kinds of radio remote control. These are mainly special solutions for one customer and no serial products.

Generally, the company sells, installs and maintains their products itself except the immobilizer systems. For this product group, Electronic Service has also regional distribution partners (e.g. car shops or garages) which have been qualified in training courses. They also sell them and are offering installation and maintenance services.

As can be seen the business of Electronic Service is divided into two parts: development of special electronics for single customers on the one side and serial production of immobilizer systems and sewerage inspection systems on the other. The turnover share of these two main business groups (serial production/special solutions) was about 50% each.
4. Company markets and competitive at the start of the AE

The market for Electronic Service Chemnitz is two-fold:

Electronic alarm, monitoring and security systems, e.g. for criminal investigation departments, are offered in whole Germany, but also in foreign countries. The same applies for our serial products, the immobilizer systems and the sewerage inspection.

On the other side it is very important for a small company to be present at the regional market. Direct contacts to the customers and a fast reaction to their needs combined with a very complex and fast maintenance service are the basis for a continuous regional basic business. That’s why we sell, install and maintain in the regional area our products ourselves. For alarm and monitoring systems solutions geared to the needs of a single customer this is very advantageous.

The turnover in the area of immobilizer systems reached about 25% of the total turnover. This demonstrates the importance of the Application Experiment for Electronic Service Chemnitz.

The immobiliser system SEW1010 is our existing product family in this area. It was introduced in the market in 1994 and is established especially in Saxony and East Germany. Additional units could be sold in West Germany, but also in Russia and South America. However, the export share was limited up to now. 95% of the SEW1010 product have been sold in Germany.

The product is recommended by the insurance companies and was awarded with the „Innovationspreis des Freistaates Sachsen 1994“ and the „Unternehmerpreis 1994“ of the journal „Die Wirtschaft“.

The SEW 1010 is preferably used for retrofitting purposes, not for the installation within serial production of new cars.

The market in the immobiliser system area is dominated by a few of big companies, e.g. Bosch and Siemens, Funkwerk Dabendorf or Startronik. But also smaller companies as Electronic Service is, offer their products. The functional features, the direct service and a competitive price are the main reasons which allow us to compete successfully. In all the five years the device is on the market, no one car was stolen. It was impossible for the thieves to neutralise the system.

The German and world-wide market for immobiliser systems is growing very fast. This mainly refers to the installation in new cars, but also for the retrofitting sector in East Europe. There are millions of systems that are sold every year. This makes it impossible to define a realistic market share for the SEW 1010, it is too small.

Nevertheless, it is the main product of our company. The following diagram shows the number of sold units in the past.
As can be seen, the number of sold units decreased in 1998, resulting in an important decline of the turnover for this product. The reason is the currently changing market. Despite the positive development in Eastern Europe, the retrofitting sector is going down in total. Most of the new cars are already equipped with an alarm system. Therefore, the functional extension to a system capable for installation within the manufacturing process, was absolutely necessary.

5. Product to be improved and its industrial sectors

The existing product, the SEW 1010, is an immobilizer system for cars, lorries, motorbikes and motorboats with fuel or diesel engine. The principle of the immobilizer is patented. The unit has been checked by the TÜV and is licenced by the „Kraftfahrtbundesamt“ (licenced with certificate ABE9571).

For the identification of the driver touchless magnetic identification sensors are used. They are individually installed in the driver’s cabin. Up to three independent identification signals can be processed. For instance, the start process of the engine may be released in dependence on the position of the window mechanism or one of the pedals. Additionally, the driver has to identify with his transportable sensor unit (card etc.) by moving it close to a sensor unit installed in the dashboard.

Once identified, up to 6 different systems of the car are released (e.g. ignition, fuel pump, starter).

The unit was developed as PCB in through-hole technology using conventional analogue and digital standard components. Figure 1 demonstrates the working principle, figure 2 the SEW unit itself.
Compared with the products of the competitors, the SEW of Electronic Service Chemnitz has a clear advantage. Most immobilizer systems work with identification elements integrated in the ignition key or use separate activation/deactivation components. In case of car-napping the thief has them available, the immobilizer...
The working principle of SEW permits only to drive away as long as the engine still works. Once switched-off, a restart is not possible anymore, all systems are blocked. Even if the thief should have the identification tag or card available, the location of the additional sensor element(s) is completely unknown to him.

The SEW had the following competitive lacks which enforced us to look for a modification of the system:

- Because of the used PCB technology and the identification concept the system was only applicable as a retrofitting system - a declining market as described before.
- All systems were released at once by the immobilizer itself. If a thief would succeed to neutralise the system, no additional blocking is possible.
- No possibility to implement the fuel pump in the release procedure (installation of one submodule together with the fuel pump in or near the petrol tank is necessary). This is the condition for a hierarchical identification process in two steps instead of the straight-forward algorithm used up to now.
- High manufacturing costs when regarding the used technology level
- No individual coded identification elements
- No self-test capabilities and service functions because of simple analogue signal processing
- No change of identification code

6. Description of the technical product improvements

The new product WFS is characterised by improved technical features and additional functionality which is implemented in the system. The most important step towards the improvement of the immobilizer is based on

- the change from conventional PCB technology to a more precise and temperature/environmental condition resistant MCM technology resulting in a higher system reliability, and
- the introduction of microcontroller technology instead of simple analogue signal processing.

The working principle is as follows:

The main unit of the immobilizer identifies the signal from the external identification tag which is read via an antenna located inside the car. The position of the antenna allows the automatic identification of the driver, no extra manipulation is necessary. He needs only to have the corresponding card or tag on board, for instance in his pocket (“hidden identification”). Additional sensor/identification elements can be optionally used.

The code is read and checked by the system. Of course different code numbers are possible, a change of them (e.g. when loosing one card/tag) is no problem anymore. After the successful identification of the driver the control unit sends a release signal to the submodule which is located in the near of the fuel pump. The state of the fuel pump is monitored by a sensor. Now the fuel pump switches on and a signal is generated which is transferred to the main unit. This data transmission is realised via optical fibres which prevents data manipulation.

The confirmation signal coming from the fuel pump initialises the next steps: Via the other channels of the unit the starter and the firing angle pulse generator are released. Depending on the application, the release of an electronic-controlled gear, clutch or
other systems (e.g. electronic motor control) relevant for operation is possible (up to 6 channels).

The system will be activated again (i.e. blocking) when the engine has been switched off and the ignition key is taken out. On the other side, the identification process is started, when the ignition key is inserted and the ignition is switched on. In the sleeping mode between the system is powerless.

The functional block diagram is shown in Figure 3.

![Functional block diagram of improved system](image)

Fig. 3: Functional block diagram of improved system

The input signal to the MCM reader unit is a modulated carrier signal and must be demodulated and filtered in high selective filter elements. The comparator element transforms the analogue signal into a digital value which is processed in the PLD later on. The PLD generates the signals for the antenna driver from the system clock. Additionally, a correction filter is implemented in order to look for failures in the data coming from the MCM and to correct them if necessary.

The antenna driver transforms the control signals into a 125 kHz alternating signal which is fed into the antenna. Passive transponders are working with load modulation and need therefore this signal to generate the operational voltage in the transponder. Additionally, the transponder uses this signal as carrier for the identification codes by modulating the coded data on the amplitude of the carrier signal.

As already discussed, this modulated signal is demodulated, filtered and A/D converted within the MCM.

Fig. 4 shows the block structure of the MCM:
Fig. 4: Block structure of the MCM

It contains the following components:

- 5 operational amplifier chips
- 1 comparator chip
- 57 capacitors
- 59 resistors

The MCM must operate without problems within the following limits without problems:

- Temperature: -40...+85°C
- Temperature shock: $\Delta T = \pm 40$K in 5 minutes
- Humidity: 0...85%

In total, the system offers the following advantages:

- absolute safety against unauthorised use by dividing the system release procedure into two steps (release signal from fuel pump as result of phase 1 is absolutely necessary to activate the other systems, in case of bypassing the immobilizer system this signal is missing and no activation will take place)
- resistant against harsh environmental conditions
- reliable code detection because of high precision of the filter elements in the MCM solution
- no special handling for the deactivation of the immobilizer system is necessary anymore
- increased functionality (different access/authorisation codes, change is possible)
- flexible application of the system for different cars is guaranteed by system parameterisation capabilities implemented in the software.
- extended application range

Figure 5 shows the control unit of the new immobilizer system. The MCM is in the package at the left side of the PCB. The additional PCB unit for the fuel pump control and the power module with the relays are not shown.
The new solution is a kind of standard product, that can be used for other applications, too. Electronic Service plans to introduce apply it also for park systems, access and entry control and other similar application areas being the business of the company. The necessary changes do not influence the basic functionality of the system. The additional effort will be small compared with the development costs and times, because it is limited to the PCB adaptation according to car specific requirements, e.g. geometry, type and material of housing, kind of contacts (connectors, fixed installation etc.) and predefined company internal component lists which have to be used. This means an additional PCB design with the related costs and effort in the range of 2..3k€. The MCM itself remains unchanged.

The next table compares the once more the functional features of the old with those of the new system:

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<tr>
<th>Feature</th>
<th>SEW 1010</th>
<th>New product</th>
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<tr>
<td>Application range</td>
<td>Only for retrofitting</td>
<td>mainly for installation in new cars</td>
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<tr>
<td>Release function</td>
<td>one step, no additional blocking</td>
<td>two steps, no bypassing of the immobiliser system possible, absolute safety against unauthorised use</td>
</tr>
<tr>
<td>Identification</td>
<td>movement sensitive sensors, fixed installation, no special identification code</td>
<td>transponder based solution, no special handling necessary (automatic identification with id-card)</td>
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<tr>
<td>Internal error detection</td>
<td>not existing</td>
<td>internal check routines</td>
</tr>
<tr>
<td>Flexibility</td>
<td>stand-alone system</td>
<td>system can be integrated in motronic (DME-digital motor electronics)</td>
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Because of the implemented functionality, the number of components in the new solution has been increased. However, due to miniaturisation it fits in the same housing as before.

The target price for the MCM is in the range of 13€.
7. Choices and rationale for the selected technologies and methodologies

The current module based on a PCB with discrete standard components did not meet the technical requirements of the car manufacturers for installation in new cars.

In the automotive industry, no general standard is defined for the electrical equipment and installation. Each big car manufacturer has its own internal standard. That’s why a multi-usable immobilizer system must have a certain flexibility to adapt it to the detailed specifications of each manufacturer. Nearly no flexibility was available with the old SEW. This was the main reason to innovate the product.

Additionally, the old analogue solution with discrete components had to be replaced by a digital one. This led automatically to the decision to implement a microcontroller (not so hard time restrictions and the limited complexity of algorithms favoured this component against the DSP). As a consequence, it was not possible to implement the new system concept described above in a conventional PCB solution, even not if using a “sandwich” construction with an additional circuit board, because of

- the resulting PCB size,
- the higher number of components,
- higher manufacturing and test costs,
- lower reliability,
- feasibility problems for some functions.

For the realization of such a project two basic principles were possible:
- Hybrid structure or
- Mixed signal ASIC in combination with an external microcontroller or an integrated microcontroller core.

The following requirements had to be met by the technology:

- Reduction of size with simultaneous increase of the functionality
- Use of effective and market introduced design tools
- Efficient manufacturing for a wide range of pieces (from <50 up to >5000 pieces) without changing the technology
- Reduction of manufacturing cost (and size) by using Dice (unpackaged chips) and direct bonding on the substrate
- Higher reliability by a reduced number of components
- Modular concept for multiple applications

The following table compares possible solutions in different technologies:

<table>
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<tr>
<th>Requirement</th>
<th>LP</th>
<th>ASIC</th>
<th>MCM</th>
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<tbody>
<tr>
<td>Size requirements</td>
<td>-</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>High reliability even in difficult applications</td>
<td>-</td>
<td>++</td>
<td>+</td>
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<tr>
<td>Flexibility of the components</td>
<td>++</td>
<td>-</td>
<td>+</td>
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<tr>
<td>HF suitable, operational speed</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Low power dissipation</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Economic production of small and medium numbers</td>
<td>++</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Numbers of pieces</td>
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The necessary flexibility for different types of cars, motorbikes etc. together with the corresponding limited number of pieces in the range of some hundreds to thousands identical units for the different types do not justify the use of mixed signal ASIC technology with embedded microcontroller core or even the design of an ASIC system consisting of an analogue and a digital ASIC. Nevertheless, the migration of the system to a mixed-signal ASIC in case of a mass production of the immobilizer for one car type is possible later on.

The used technical identification principle has one disadvantage: The identification process with transponders is based on the modulation of the amplitude with only very small signal differences between useful signal information and carrier signal/noise. In order to make the system as much reliable as possible, a very precise signal evaluation must be made. Therefore, the necessary filter elements must work with high precision also in a harsh environment as it is the case in automotive applications (e.g. temperature ranges between –40...+85°C).

The functional objective to introduce a handling-free identification process ("hidden identification") required an additional improved selectivity and precision of the data receiver and decoding unit. This led to the decision to apply a ceramic based MCM structure. The choice of the MCM-C permits the mounting and bonding of the components of the reader unit (bare chips included) on a ceramic substrate. Connections and resistor structures can be printed and resistors will be laser trimmed.

The MCM is shown in Figure 6:

![Fig. 6: The MCM Unit](image)

The MCM-C technology combines the necessary miniaturization with a higher reliability and a competitive price, which cannot be achieved e.g. with a SMD solution:

- The ceramic base material makes the system more temperature resistant
- The housing in a metal package improves EMC and insensitiveness against external disturbances
- The MCM structures offer a high precision and a linear behaviour of the whole system
- The use of dice makes it possible to integrate the filter elements on a small
Especially the improvement of the reliability parameters is essential, because the MCMs are used in a very harsh environment with temperature ranges between -40 and +85°C. Additionally, our contacts with GEMAC will allow also the future volume production of the MCM without problems.

The first idea to implement the microcontroller core at the MCM was overcome in the specification. The reason is that the unit would have lost its flexibility at all. Whereas the filter elements are necessary for each application, the microcontroller type is varying in dependance on the internal standards of the car manufacturers. That’s why a separate microcontroller was placed on the board.

For the project the AT90S8515 of ATMEL was used. This powerful 8 bit microcontroller was selected because it

- has a reasonable price
- can meet all requirements defined in the specification
- is a market-introduced component (i.e. tools and service are available, it will be on the market also for the next years)

It is used as central control unit within the system and is responsible for all control, verification and memory-related operations.

The following tools were applied:

<table>
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<tr>
<th>Analog components:</th>
<th>MicroSim SPICE</th>
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</thead>
<tbody>
<tr>
<td>µController:</td>
<td>ATMEL-AVR-Assembler</td>
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<td></td>
<td>ATMEL-AVR-Studio</td>
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<td></td>
<td>ATMEL-AVR-Emulator</td>
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<tr>
<td>PCB:</td>
<td>Mentor-Graphics</td>
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<tr>
<td>Multi-Chip-Modul:</td>
<td>In-house system GEMAC</td>
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</table>

All software and hardware components were simulated and tested continuously. This concerned the MCM, the PCB, but also the software modules. After each task, the result was reviewed.

For components to be used in the automotive industry a field test is absolutely necessary. It was executed under real conditions by installing the system in a car. The prototype was checked in the laboratory before.

8. **Expertise and experience of the company**

The employees of Electronic Service Chemnitz are experienced developers and distributors of electronic alarm, monitoring and security systems. The company has special know-how in the area of immobilizer systems. There is no other competitor on the market offering devices with the same technical principle.
The microelectronics experience was restricted to the development of analogue and digital systems using discrete standard components. Of course the company is familiar with test strategies for PCBs in serial production. The development engineer had some basic knowledge in software programming resulting from its technical college studies.

The PCBs were partially designed in-house with the PC CAD system CADDY. More complex designs were outsourced. Special know-how is available for the design of HF systems and corresponding data transmission methodologies.

Of course we were also able to manage such a PCB project from the organisation and technical point of view.

The company had neither knowledge nor experiences with the management of hybrid and MCM projects (planning, contacting suppliers to buy unpackaged chips, selection of tools etc). The necessary know-how for a detailed specification and the design tasks was lacking, too.

The following table describes the existing and missing experiences in detail.

<table>
<thead>
<tr>
<th>Existing knowledge &amp; experiences</th>
<th>Lacking know-how</th>
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<tr>
<td><strong>1. Project Management</strong></td>
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<tr>
<td>- Analysis of tasks (technical and financial feasibility) for conventional electronics systems (PCB, standard components)</td>
<td>- Selection of new technologies and design methodologies/tools</td>
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<tr>
<td>- Market analysis, business plans for such kind of projects</td>
<td>- Cost and project planning for MCM or hybrid projects</td>
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<td>- Development and production planning</td>
<td>- Selection of subcontractors and definition of interfaces (evaluation of own capabilities)</td>
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<td>- Sales and marketing</td>
<td>- Management of design and manufacturing</td>
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<td>- Serial production requirements</td>
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<tr>
<td><strong>2. Technical work</strong></td>
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<tr>
<td>- Development of systems with discrete standard components</td>
<td>- Overall knowledge in new microelectronics technologies</td>
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<td>- PCB design in through-hole technology</td>
<td>- Design and application of hybrid circuits</td>
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<td>- PCB test</td>
<td>- Design of multi-chip-modules (MCM)</td>
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<td>- HF and video technology</td>
<td>- Implementation and test of MCMs in own products</td>
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<tr>
<td>- Check and test of electronic units</td>
<td>- Microcontroller programming and application</td>
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</table>
9. Workplan and rationale

A first project schedule was set-up already in the preparation phase of the Application Experiment together with the TTN. This was a kind of first technical management training giving us a first experiences how to plan a MCM project.

In principle, the work was executed as planned. However, we had some problems to follow the planned schedule. Other, additional businesses prevented to finalise the project in time. This resulted in a project extension of three months. This did not imply higher effort and costs than originally planned.

On the other side, some of these activities were very useful for the market introduction of the immobiliser system. For instance, some car manufacturers were contacted to negotiate additional sales.

Additional know-how was acquired in microcontroller technologies. In order to be able to modify the implemented software and to adapt the system to the requirements of different applications it was necessary to transfer additional software know-how in microcontroller programming. The selection of the best suitable type as well as the programming step and software test were made together with the subcontractor. Electronic Service is now able to specify algorithms, to evaluate the software and to modify corresponding parameters. Furthermore, we have got basic knowledge in programming methodologies and assembler language which will enable us to do next tasks in this area alone or only with little assistance “on demand”.

When preparing the submission and during the specification task, a risk analysis was made together with the subcontractor. The main issues were:

- to match our technical requirements (e.g. filter parameters, functionality under harsh environmental conditions,...) with the capabilities of the functionality
- to guarantee the availability of the dices (for prototyping, but also for mass production)
- to achieve a first-time-right design

The risk to stress the technology too much was completely excluded in the specification task together with the subcontractor. Parameters which could not be realised were modified. The final specification review confirmed the complete technological feasibility, there was no risk anymore.

All risks related to the unhoused chips were sorted out by using the experiences and contacts of our subcontractor. This was also a very important lesson learned for us. In the future we will be able to manage this activity ourselves.

The design risk itself was minimised by spending a high effort for design. We had planned two iteration cycles for design-simulation-modification.

A detailed design review with the subcontractor before prototyping and the awareness resulting from the specification to have no problems with the technology itself caused us not to plan two iterations for prototyping. Our objective was "First time right". However, we discussed with the subcontractor a contingency plan which would have allowed to manufacture modified prototypes in a second run. Fortunately, this was not necessary.

The resulting workplan is shown in figure 5. The dotted line represents the schedule as planned in the Technical Annex, the full blue line the real work executed in the project.
As can be seen, the work was started in April 1997. The project was finished with the tested prototype in April 1998.
The following table describes the contents of the different tasks:

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<tr>
<td>Manufacturing, product implementation</td>
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<tr>
<td>Evaluation and test</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Contents</th>
</tr>
</thead>
</table>
| Management | • Project Management  
 • Reporting  
 • Dissemination activities  
 • Final Report |
| Training* | • Training Technical Management, (Project planning, overview of different technologies, selection criteria and capabilities)  
 • Training hybrid and MCM design  
 • Training microcontroller technology  
 • Training test strategies for MCMs |
| Specification | • Specification of the immobiliser system at system level  
 • Selection of components and microcontroller type  
 • MCM specification  
 • Specification of MCM and system interface  
 • Specification of software algorithms |
| Design, Programming & Manufacturing | • MCM design  
 • Board design  
 • Software Modules  
 • MCM production  
 • Board prototyping |
| Test | • Prototype test  
 • Immobiliser assembling  
 • Installation in a car and field test under real conditions  
 • First EMC test |
The work and responsibilities were divided between First User and subcontractor as follows:

<table>
<thead>
<tr>
<th>Task</th>
<th>Electronic Service</th>
<th>Subcontractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>Project related management</td>
<td>Online assistance as necessary, assistance in technology oriented management (i.e. getting dice)</td>
</tr>
<tr>
<td>Training</td>
<td>Participation in training</td>
<td>Management Training (Project planning, technology overview) design of MCMs, microcontroller technology</td>
</tr>
<tr>
<td>Specification</td>
<td>Function and technology related activities (implementation of functions, selection of components, block structuring, interface definition)</td>
<td>Assistance in technology related specification activities</td>
</tr>
<tr>
<td>Design, Programming &amp; Manufacturing</td>
<td>MCM design and simulation prototype board design &amp; simulation</td>
<td>Design assistance starting with continuous co-operation at the beginning and ending with “assistance on request”</td>
</tr>
<tr>
<td>Test and evaluation</td>
<td>Prototype and field test EMC check</td>
<td>Technology-related assistance</td>
</tr>
</tbody>
</table>

Table 3: Division of work

The table also describes the know-how transfer process within the project. Starting with training courses, the subcontractor was responsible for, the knowledge was transferred in "Learning-by-Doing" methodology. The engineers of Electronic Service were responsible for the specification and development task, assisted by the subcontractor as necessary. Of course more help was needed when beginning a task. Later on, assistance was given on request. The MCM manufacturing was not our job. Here the subcontractor was responsible again. However, we accompanied this process in order to get a better understanding of this technology. All test activities were carried out by Electronic Service, GEMAC gave only technology-related assistance.

The following table summarises the planned and spent efforts of Electronic Service and subcontractor GEMAC.
## 10. Subcontractor information

The main competency of Electronic Service Chemnitz is the application oriented development of serial products and special solutions in the field of electronic alarm, monitoring and security systems. As described above, the company’s specialists have experiences in the management of such projects and the development of hard- and software using standard components.

The company had no experiences in hybrid and MCM technologies and an additional lack in the field of microcontroller programming, neither from the management, nor from the technical point of view.

Our objective during the preparation of the AE was to find a subcontractor for a wide range of activities. Of course an excellent know-how in the whole area of hybrid and MCM technology as well as microcontroller application experiences were absolutely necessary.

On the other side it was our objective to learn as much as possible within the Application Experiment in order to be able to solve such problems in the next time mainly ourselves. This resulted in an additional requirement: A possible subcontractor had to be experienced also in the co-operation between two partners, especially in training and know-how transfer activities. In order to avoid information lacks and to guarantee best practice in all tasks by organising a continous workflow we preferred one qualified subcontractor for all know-how transfer and design activities.

Electronic Service had an additional demand: Development and manufacturing of the units should also be done by one cooperation partner. As a result of the design, the subcontractor is already familiar with all technical details. This prevents difficulties and guarantees a high flexibility in case of necessary modifications.

The geographical distance should be as small as possible in order to allow direct access.

Hence, the following requirements had to be met by the subcontractor:

Training activities for the technical management of MCM projects (selection of technologies, components and tools, definition of a workplan, costs, interfaces to subcontractors (what is effective to do ourselves)...)

<table>
<thead>
<tr>
<th>Task</th>
<th>First User</th>
<th>Subcontractor</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Role</td>
<td>Effort plan</td>
<td>Cost plan (k€)</td>
</tr>
<tr>
<td>Management</td>
<td>Responsible</td>
<td>20 22 3.2 3.5</td>
<td>Assistance 0 0 3.2 3.5</td>
</tr>
<tr>
<td>Training</td>
<td>Participant 24 28 3.8 4.9</td>
<td>Responsible 5.1 5.1 8.9 10.0</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>Responsible 50 45 8.0 7.2</td>
<td>Assistance 7.4 7.4 15.4 14.6</td>
<td></td>
</tr>
<tr>
<td>Design/Manufacturing</td>
<td>Responsible 83 95 12.3 15.2</td>
<td>Assistance 14.3 14.3 26.6 29.5</td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>Responsible 60 50 10.1 8.0</td>
<td>Assistance 2.1 2.1 12.2 10.1</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>237 240 37.4 38.8</td>
<td>28.9 28.9 66.3 67.7</td>
<td></td>
</tr>
</tbody>
</table>
Know-how transfer in the field of MCM design and microcontroller application/use of corresponding tools in form of training courses followed by „Learning-by-Doing“ activities
Complex and „online“ design assistance as necessary
Ideally manufacturer of the prototypes and later on for the serial devices

We selected GEMAC Chemnitz as subcontractor. The company is experienced in training activities as well as practical designs of hybrid circuits, MCMs and microcontrollers. Being a private company, GEMAC is experienced in all „practical“ aspects of the application of microelectronics technologies. The company isn’t a distributor of special tools or components and can give independent advise based on their own experiences.
Within different projects the effective know-how transfer to customers was demonstrated. Additionally, GEMAC has an own manufacturing department and is located only some kilometers from Electronic Service.

The subcontractor was responsible for the training activities and the prototype manufacturing. He assisted in the design steps as demanded and as necessary. It was important to have direct access to the specialists of the subcontractor at any time by phone and by direct contacts.

The basis was a contract between the partners in which all know-how transfer, development and manufacturing issues were defined. Basis for the successful completion of the contract was the working prototype. Bonus or penalty clauses were not contained (except the common terms of business). Of course both parties declared to keep all detailed technical or business information confidential. Electronic Service owns all results.

11. Barriers perceived by the company in the first use of AE technology

Electronic Service Chemnitz is a small company which has to react very fast to the customer’s requirements in order to stay successful on the market. The ability to develop very practical oriented solutions is the bonus the company has against the big competitors.

Unfortunately, the daily business produces in most of the time a kind of overload which does not allow to spend much effort in the qualification of the staff, e.g. the introduction of new technologies. That’s why it was not possible to extend our knowledge to innovative microelectronics as MCM technology is, even if there was no psychological barrier to do it.

As a result of a market study we recognised to have the choice to be kicked out of the market or to introduce now a new technological level. Some new product features, e.g. the necessary flexibility, improved reliability, reduced size and number of components, cannot be realised with our existing technology level. Hence, the daily business was no reason anymore to postpone the necessary qualification. We had to postpone the daily business (or to do it at least in parallel).

But there was a real important barrier: The introduction of MCM technology could not be realised without competent assistance. Even if it should be possible to go through a learning process starting from a training course, via first design steps in “try and error” mode up to a test of the developed solution, the effort, the risk and the costs are too high.
The assistance of an experienced subcontractor is therefore absolutely necessary, but how to find the best partner?

Based on the experiences of the company, Electronic Service was already familiar with the management of design projects using microelectronics technologies. However, there was an information lack concerning the issues of a MCM application (e.g. time schedules, price estimations, selection of tools and components, where to get the dices) and the use of microcontrollers. Of course we had essential know-how barriers in the technical work, e.g. in design, simulation and test methodologies and missing experiences in the system specification: What can really be implemented using the MCM technology?

The main barriers to be overcome in the Application Experiment were:

1. **Project planning barrier**
   No reliable information about the costs of the project, the necessary design effort, component costs and availability, production costs for prototypes and serial components. Should the project be realised with an ASIC, discrete components or a hybrid/MCM? Which kind of microcontroller should be implemented, which tasks should be done in-house and what should be outsourced?

2. **Project management barrier**
   Missing knowledge about the organisation and the schedule of a MCM project (including contingency planning). Furthermore, selection criteria for a subcontractor and the criteria for the organisation of an effective co-operation were unknown.

3. **Distributor/foundry interface barrier**
   If you start a MCM project, the contact persons or companies are normally unknown to you. Even if you have this information, there is a kind of ignorance by the suppliers if you won’t order immediately 50,000 dices. Furthermore, there are doubts concerning their ability to deliver and the real pricing.

4. **Technology barrier**
   No knowledge in the technology characteristics and the possibility to realise functional features (Is it possible or not?). What are the interface conditions from design to manufacturing? Missing experiences about the electrical, thermal and mechanical conditions of a hybrid chip / MCM.

5. **Microcontroller application barrier**
   Which type of microcontroller should be used? How to integrate the software modules in the whole system? Which interface conditions have to be realised between the software and the hardware parts of the system? Missing programming and software test knowledge.

6. **Design barrier**
   Because of the lacking technology know-how the selection of the best design methodology and tools as well as the design methods themselves were unknown. Another problem is that you cannot ask questions if you don’t have a minimum of basic knowledge – i.e. the temporary assistance by a partner (e.g. by phone) is useless. You need continuous help at least when doing the first steps.

7. **Test and evaluation barrier**
Electronic Service had insufficient knowledge how to test a MCM. Which kind of test strategies can be used?

It became clear for us, that we needed continuous help for the whole project, starting from the project planning and continuous management up to the last test activities. Because the necessary efforts in this case are doubled (you have to finance your own expenses and those of the subcontractor) Electronic Service had a strong financial barrier.

12. Steps taken to overcome the barriers and arrive at an improved product

The Application Experiment helped us to overcome successfully the barriers mentioned in the last section.

1. Project planning barrier

One of the requirements to submit a proposal for an Application Experiment was to select the best technology for the project realisation and to setup a workplan. The close cooperation with the TTN was a first kind of know-how transfer in this area. Together we defined a rough block concept of the immobilizer system harmonizing the technological requirements with our project ideas at the same time. Electronic Service already learned something about new innovative micro-electronics technologies, especially

- Technical and functional capabilities of MCM technology, availability of dice
- MCM design features and tools
- Realistic definition of workplan, costs, duration of the project

Of course we made within the AE a replanning of all foreseen activities after having finished the detailed specification. In this way, our uncertainty to plan an own development project of such a complexity using an unknown technology was overcome.

2. Project management barrier

When starting the project, all management details were discussed with the TTN, e.g. the criteria for the selection of a subcontractor. We worked out together the detailed schedule including the division of work. Best practice in management issues was transferred within the Management Training and verified within the project itself. Electronic Service is now familiar with the main features to manage a project, even for the introduction of a new technology.

3. Distributor/foundry interface barrier

We were involved in all negotiations with the distributor to order the dice. The subcontractor explained in detail the interfaces and requirements to supply a MCM design to a manufacturer. For better understanding, Electronic Service was involved in the manufacturing process in form of informal visits.

4. Technology barrier

Within the MCM training course a lot of detailed knowledge about characteristics and capabilities of the MCM technology was transferred. In the specification task, these capabilities were harmonised with our project ideas. In this way we learned to use all technology features and understood also the technology restrictions.

5. Microcontroller application barrier

In close co-operation with the subcontractor we learned to specify software-hardware interfaces, to parameterise a system in order to make it flexible and to test the
developed software. We got an overview about software methodologies and programming methods and learned to select appropriate microcontroller types for our application. One of the most important barriers for replacing the old analogue based systems by software solutions was overcome.

6. Design barrier
Within the design task the practical know-how in MCM design methodologies was transferred. Electronic Service got knowledge in handling the design tools, and learned to setup test strategies. The combination of training activities and immediate „Learning-by-Doing-Steps“ was the most effective for us.

In this way, know-how barriers in design and simulation technologies as well as MCM layout generation were overcome.

7. Test and evaluation barrier
The review of the project results at the end of each task minimised the design risks of the project. Additionally, the subcontractor transferred knowledge in test methodologies for MCMs as well as the whole prototype test. All essential functions were checked. The acquired knowledge enabled Electronic Service to make the field test itself. For this purpose, the immobiliser system was installed in a car.

The financial barrier was overcome due to the calculated payback periods during the planning stage. Of course the modalities of the FUSE project supported the start-up. The economic benefits resulting from the introduction of the product to the market will enable us now to finance a next development ourselves.

For instance, are planning to use the MCM and the whole immobiliser system for different car, motor-bike and boat types. The adaptation of the system is a first replication of the know-how transferred in the Application Experiment.

On the other side, the used principle can be applied also for other access and entry control systems to identify and authorise persons, such as bank access systems, intelligent controllers for elevators etc.

13. Knowledge and experience acquired
Within the Application Experiment the staff of Electronic Service Chemnitz acquired the following knowledge:

- **Technical management of projects using MCM technology**
  This point covers for instance the definition of realistic objectives for a development using MCM technology, the definition of interfaces to partners including their selection, the setup of workplans and financial breakdowns, as well as investigations to evaluate the own position and competitiveness on the market. Especially we learned the importance of milestones and contingency planning in order to modify the project planning according to unforeseen problems from outside, but also to occuring technical problems (availability of components, necessary modifications in the spec, ...). Furthermore, we are now able to introduce other technologies in the future, too.

- **Specification of MCM solutions**
  Electronic Service Chemnitz is now able to specify MCM applications without essential assistance and is familiar with the technology features (design rules, technical parameters, application conditions,...)
• **MCM design, simulation and manufacturing**
The specialists learned how to use the existing tools for MCM design. Already familiar with the application for conventional design activities, they had to learn additional MCM layout rules. Electronic Service got an overview about the manufacturing process itself and the necessary interfaces between design and production.

• **Microcontroller application and programming**
The specification of microcontroller based development tasks, choice of corresponding microcontroller types and programming/test strategies were learned. Electronic Service is now able to substitute the old analogue signal processing principle by a combination of software and mainly digital hardware systems also in other applications.

• **Test strategies for all levels of a development**
A design can be checked now in all tasks against the system specification. Our specialists are familiar with simulation and test methods for MCMs and introduced software verification methods. The field test of the immobilizer was a first kind of internal replication.

### 14. Lessons learned

In the project we have learned all necessary things to plan and to manage MCM projects. Furthermore, we learned to design and to test such components. In detail, the following lessons were learned, that were not clear for us before:

• In the project planning, time and costs must be planned very carefully. Contingency plans should be made in order to avoid problems. At least, other businesses will overlap such a complex project. In any case, time reserves should be foreseen.

• In the specification task the possibility to use a customer specific solution for more than one product should be discussed. This makes a development more economic. In this project phase, modifications of the basic concept to meet all requirements are still possible. In our case, a solution that is multi-usable for different car and motor-bike types was specified.

• MCMs combine the advantages of a customer specific solution (miniaturisation, increased reliability, lower price) with the possibility to manufacture them also for smaller number of pieces.

• In order to justify the effort for such a development, a market analysis should be made together with the feasibility study. In parallel, potential customers should be contacted. This allows (if the discussions are positive) the implementation of additional functional features making the system applicable for the partner.

• The choice of a subcontractor for a first hybrid or MCM project is very important. It should be guaranteed that the company has not only the necessary design competencies, but also close relations to the suppliers of dies. A qualified die selection and an agreement to guarantee their continuous supply is of high importance. Existing manufacturing capabilities at the subcontractor’s site are very useful.

• Best practice in know-how transfer is the learning-by-doing methodology in each step of a project. Based on a short theoretical training course, the design task should be
done selfstanding and with assistance of a subcontractor. In this way best practice is transferred. A lot of questions only raise in the real work and don’t appear in a training course!

- Each deliverable should be reviewed carefully with the subcontractor in order to have a reliable basis for the continuation of work. An additional iteration within one task is less time-consuming than the repetition of the whole design cycle.

- The introduction of each new technologies follows in principle the same guidelines. From the management point of view you have to estimate necessary costs, the manpower to be spent and to look for subcontractors who are assisting the work. Furthermore, a rough overview about the technical features of the technology to be used is necessary. This must be understood before starting such a new development. We learned to find subcontractors, we know what are the important issues for the know-how transfer and what should be the interfaces between our company and the subcontractor. That’s why we are convinced that we will be able not only to replicate MCM and microcontroller projects, but also to introduce other technologies, e.g. FPGAs. This is one of the main lessons learned.

The minimum knowledge transfer for a company to introduce MCM technology should include:

- Technical management issues
  You must have a rough overview how much a MCM development will cost and how much development time is necessary. This also helps to assess an offer of a subcontractor, if the work to should be outsourced. Furthermore, an overview of tools and design/programming methodologies is necessary to specify what you want. At least the specification and selection of components should be done in-house or together with the subcontractor.

- Design
  In the technical area, a design know-how is very effective. It gives you the necessary flexibility to modify the final product later on. Anyway, if the company has no resources, this task can be outsourced.

- Evaluation and test
  In the product test, own knowledge about test strategies and implementation of MCM systems is necessary to test the final result of the development under real conditions.

15. Resulting product, its industrialisation

The result of the Application Experiment is a prototype that works correct as defined in the specification. It was installed in a car and checked in a field test. Up to now, there are no general function problems.

As already described in one of the last chapters, one specific requirement for immobiliser systems to be used in the automotive industry is the certification by the German Kraftfahrtbundesamt. In order to get this certificate, additional activities are necessary:

- The installation and functionality of the immobiliser system must be tested for a longer period (>9 months). This process is still going on.
- One of the main conditions is the EMC test of the device. In the meantime, first preliminary tests have been executed. The final EMC test will be done until end of
May 1999.

Our plans are to start in summer 99 a marketing campaign for the improved system. We will present it to several car and motor-bike manufacturers. For this purpose it is necessary to adapt and modify the system for the installation in different car types. This will cause additional efforts for Electronic Service Chemnitz. First units will be sold in autumn 1999.

Of course expenses for marketing, presentation at fairs and advertisement have to be planned. The next table presents the schedule for industrialisation and the necessary expenses.
<table>
<thead>
<tr>
<th>Task</th>
<th>Planned for...</th>
<th>Effort/Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC test – preliminary</td>
<td>March 1999</td>
<td>10 pd + third party 5.000€</td>
</tr>
<tr>
<td>Finished Field Test (installed prototype) EMC test - certification</td>
<td>May 1999</td>
<td>40 pd - 12.000 €</td>
</tr>
<tr>
<td>Modifications for different car and motor-bike types (PCB modification, test,...)</td>
<td>Until September 1999</td>
<td>40 pd + material 15.000 €</td>
</tr>
<tr>
<td>Certification Kraftfahrtbundesamt</td>
<td>Until September 1999</td>
<td>20 pd + third party 30.000 €</td>
</tr>
<tr>
<td>Marketing campaign /fair presentation / advertisement</td>
<td>July-December 1999, (continued later on)</td>
<td>25.000 €</td>
</tr>
<tr>
<td>Market introduction</td>
<td>October 1999</td>
<td></td>
</tr>
</tbody>
</table>

That means total industrialisation costs of about 80.000 € (an effort of 5,5 person months is included), i.e. they are in the range of the development costs.

The manufacturing of the serial components of the MCM and the PCB board will be done by our subcontractor. The company is already familiar with all functional and technical issues. In this way, the costs for the production start will be a minimum, the risk of technical difficulties is low.

As already discussed before, we are planning to use the MCM and the whole immobiliser system for different car, motor-bike and boat types. The adaptation of the system is a first replication of the know-how transferred in the Application Experiment.

On the other side, the used principle can be applied also for other access and entry control systems to identify and authorise persons. Developments are planned, contacts with potential customers have been started.

Other projects in the sector of supplementary safety units for safes or in parking systems are discussed currently.

The extension to other application areas will increase the number of MCM basic modules resulting in lower manufacturing costs.

We will be able to develop a new MCM in the future based on the acquired knowledge. However, it will be necessary to contact our subcontractor for detailed technical and economic advise to maximise the real profit attainable from the existing technology.

With the new product we will have a very good competitive position on the market. The principle is unique and not offered by other competitors. The main focus of the immobiliser system is now the installation in new cars at the manufacturer's site. Of course Electronic Service is competing in this area with big national and international companies. The introduction of the product into the automotive sector not only depends on the technical features, it is more a "strategy problem" of the automotive industry as described in the next section. However, we have now with the improved immobiliser system a much better starting position as before which is clearly demonstrated by the first negotiation results with the car industry.

Furthermore, the principles and methodologies learned in the Application Experiment are also a good basis for a later implementation of the system into a mixed signal ASIC. If the negotiation with a big car manufacturer is successful, Electronic Service will have the need to migrate the design.
16. Economic Impact and improvement in competitive position

With the Application Experiment Electronic Service Chemnitz has been made an essential step towards an improved competitive market position in the German, but also the international market. The new system is characterised by better functional features and a better price when comparing it with the products of our competitors. The main advantages are:

- the absolute manipulation safety against unauthorised deactivating of the system by system release in two sequential steps
- the extension of the application area from retrofitting to installation within the manufacturing process of new cars (the separate power module is not necessary in this case)

Negotiations with potential customers in both areas have clearly shown the interest of the market. Our market in the retrofitting sector will be Germany, Austria and other European countries. The distribution and installation will be done using our existing distributors and maintenance partners.

Possible customers for the installation of the immobiliser system in new cars are mainly located in foreign countries. Currently, Electronic Service has negotiations with companies in Turkey and South Africa. First sales are planned for 2000.

The other potential market is Eastern Europe. Most of the cars in the former Soviet Union and other COMECON countries are not equipped with such a system. On the other side, the criminal rate enforces the people to install immobiliser systems. They have recognised in the meantime that conventional systems with only acoustic alarm signals (as mainly offered there) are useless.

Russian car manufacturers are also interested in the improved WFS system, negotiations were very promising. A current barrier is the situation in the countries. Because of economic difficulties, negotiations are complicated and time-consuming. Nevertheless, the contacts will be continued in order to keep open the door.

The introduction of the system to German car manufacturers is quite difficult, because it is nearly impossible to become a supplier for them as a small company (independent on the offered product).

Based on the market studies and our customer contacts Electronic Service is convinced that the following economic figures and the sales forecast is realistic. We started the calculation from a conservative point of view.

The profit will not only result from increased sales figures, but also from reduced manufacturing and test costs for the existing product. The hardware standardisation permits higher production batches and therefore a more favourable price. Further economic improvements are as follows:

- Because of the enhanced functionality a higher price can be achieved on the market.
- The MCM unit can be used for additional product developments as tested base component.
- The necessary effort is lower, the time-to-market period significantly shorter.
Compared with the prices of our competitors we are at the low end of the price range. A direct comparison is not possible, because the functional principle which was described in this document is a completely new one.

As already described in section 4, the company would have lost its market share without the described product improvements and without the introduction of the new technologies. The following development of sales figures would have been expected:

The market introduction of the new product allows us not only to compensate this loss. We will improve our market share significantly, as shown in the next diagram. We assume a product life time of at least 5 years. Figures for retrofitting purposes and installation in new cars as well are included:

Our main objective was to introduce our products directly in the manufacturing process of new cars. The forecast and the resulting profitability are as follows:
Even if the forecast for new car systems seems to be realistic, because the Turkish partner as well as the South African partner declared their strong interests, the payback period for the prototype development within FUSE should be calculated only on the basis of the retrofitting devices. These data result from the market investigation and will be reached in any case. Hence, the payback period only for the development costs will be about 2 years. Assuming a product life time of at least 5 years, the total ROI for the FUSE investment will be about 1000%. The reason for this high ROI is, that immobiliser systems are a real mass product. The use of advanced technologies opened up new markets for Electronic Service resulting in these high sales figures.

17. Target audience for dissemination throughout Europe

The Demonstrator can be used for a wide range of target audiences. Electronic Service is a typical small enterprise with existing basic knowledge in microelectronics. Developments with discrete analogue and digital components were already successfully made, experiences in the management of such projects were also available.

It was necessary to introduce a more customer-oriented mixed signal technology to stay competitive on the market. ASICs are not applicable because of the limited number of pieces for one application. Hybrid/MCM solutions are a good choice in case of mixed signal processing. Unfortunately, know-how in technical management and technical work was not available.

This situation is similar for a lot of companies, not only in the automotive industry sector. Small companies (often guided by a technical oriented management) have the same barriers and the same lacking know-how. They can benefit from the management and technical experiences described in the demonstrator.

Best practice aspects which should be disseminated to other companies cover the following issues:

- Management of digital MCM designs, especially the kind of co-operation and division of work between subcontractors and First User of this technology, setup of workplans and cost estimations
- Internal project planning: Best approach to combine the daily business with a MCM development
- Market chances even for small companies resulting from the introduction of state-of-the art products
- Experiences in negotiating the supply of dices
- MCM and hybrid specific design methodologies
- Simulation and test strategies for such a kind of design
The methodology to plan and execute a successful know-how transfer can be shown very good with the project. Also the financial advantages and the increase of competitiveness are obviously to stimulate other companies.

Thus the typical target audience are companies with a product on the market, with discrete technologies, who need to improve the product using innovative MCM technology in order to stay competitive. They have the same barriers in management and project work and can therefore benefit from our experiences.

Especially for companies from the industry sectors

- Parts and accessories for motor vehicles (3430)
- Alarm systems (3162)
- Industrial process control (3330)

...can directly benefit from our application oriented experiences.

Possible approaches for dissemination are:

- Companies with the same culture and size
- Small companies which are managed more from the technical point of view (manager is engineer)
- Companies with the same technology level in-house (design of analogue and digital systems using discrete components) and the same technology step
- Companies in East Germany (to allow direct information exchange)

A replication within Europe should be also possible for the same target groups as described above. The experiences we made might be useful for companies outside Germany, too. That’s why this AE has a good added value for the FUSE portfolio.