Abstract

The combined company TÜRKTÜRK ELECTRONIC GMBH (T+T) and INTERTON HÖRGERÄTE GMBH is developing, manufacturing and selling hearing-aids. T+T does the developing and manufacturing, and the subsidiary company INTERTON HÖRGERÄTE is responsible for the selling and the marketing.

The company started the AE with the aim to develop an ASIC, which replaces the mechanical trimmers in the hearing-aid. This would offer several advantages, including improved performance, miniaturisation, applicability to both current and future hearing-aids, and ease of programming.

The miniaturisation affects the ITE (In-the-Ear) and CIC (Completely-in-Channel) hearing-aids of the smallest size, which represents a niche market for a small company like T+T. These aids have a higher cosmetical use than BTE's (behind-the-ear). Larger companies like SIEMENS or PHILIPS are pushing ahead with using digital signals processing ICs (DSP). The AE allows the company to participate at this technology. The company gained advantage in all aspects of low power mixed signal ASIC methods, so that they take an active part in further designs. The experiment costs were 155,000 ECU with a duration of 15 month. The increase in sales of the new product will allow the company to increase its profit in 1999. The payback period will be 2 years after introducing the product in the market. The product lifetime is about 5 years, the return on investment is about 300%. The time to market is about 1 year.

In general the results of this AE will be of interest to companies, operating in the high-end hearing-aid and acoustic market.

1. Company name and address

TÜRK + TÜRK ELECTRONIC GMBH
AM DÄNNEKAMP 15
D-51469 BERGISCH GLADBACH
Germany

2. Company Size

TÜRK+TÜRK ELECTRONIC GMBH and its subsidiary company INTERTON HÖRGERÄTE GMBH employ 78 people, with 50 people working in the production and 3 electronic engineers. The revenue of the company is about 8 MECU.

3. Company business description

TÜRK+TÜRK ELECTRONIC GMBH is developing and manufacturing hearing-aids which are sold by the INTERTON HÖRGERÄTE GMBH. The company products include In-the-Ear, Behind-the-Ear and custom-made hearing-aids. The hearing aids are sold to audiologists that configure the device to the specific hearing profile of the patients. With some of it’s products TÜRKTÜRK competes against larger companies, but some specialised devices address a niche market with less or no competition. The company does the complete manufacturing of mechanical parts of the hearing aids in house. It includes moulding of cases, assembly of the complete hearing aids, and for some devices adaptation of the case to the patients. There is a small department to work on new devel-
opments, which not only includes mechanical and electronic design but also development of fitting procedures and nowadays of fitting software. The company used to be depending on electronic component suppliers who are not innovating on their own.

Industrial sectors: Medical devices (Code: PH)

4. Company markets and competitive position at the start of the AE

The company's products are designed to help people with hearing-impairment to hear with the help of "electronic". Over the sales company INTERTON HÖRGERÄTE, T+T has 1200 customers world-wide, with sales of over 50,000 units per year. Domestic sales have a value of about 50%. Whereas the MEGA-POWER, with a very high gain, is a very important product in this market. The company is presently among the 6th largest hearing-aid suppliers in Germany. The main competitors in the world-market are SIEMENS, OTICON, PHILIPS, PHONAK, BERNAFON, BELTONE and STARKEY. T+T does not compete with them head-on, but tries to create a niche market for high-quality and high-technical hearing-aids.

Driven by the problem of insufficient tolerances and the dimension of mechanical trimmers, some of their larger competitors have introduced the development of amplifier ICs with EEPROM, in which relevant fitting parameters can be stored, such as Low-Frequency Cut, High-Frequency Cut, Gain-Control or AGC (Automatic gain control). But they have either used IC technologies which lead to a high amplifier noise or programming schemes which are not up to date to the new developments in the acoustic field.

Up to the introduction of the new technology, T+T was a "me too" company, which used conventional technology that is used by everybody. With the new technology, the company is able to be innovative and to sell innovative technologies.

5. Product to be improved and its industrial sector

Hearing-aids take in surrounding sound with a microphone, electronically amplifying the microphone output and then convert this back to sound energy in the receivers. Normally, hearing-aid amplifier-ICs need mechanical trimmers for the adjustment of frequency response. But those trimmers take a lot of space and even have quite insufficient tolerances because of the thickfilm technology. The MEGA-POWER e.g. consists of about 42 discrete components.
The company started to develop an ASIC with analogue trimmers which would be controlled digitally, but understanding the benefits of digital processing, a lot more digital features were implemented. And the now used band-filtering would not be possible in analogue technology: The now used ASIC works in the following way:

The IC is used to create a 7-band hearing-aid. Except of microphone and receiver, analogue pre-amplifier, AGC (Automatic gain control) for signal limiting and other passive external components like capacitors, resistors, switches, telephone coil and a battery. The hearing-aid uses a 1,3V battery as power supply. A total gain of 80dB from microphone to the receiver should be reached with a minimum gain of 50 dB, just like the other hearing-aids.

The programming of the ASIC within the hearing aid includes some AGC parameters and gain values for different frequencies. The programming is done via an external programming-interface (HiPro) and the internal chip-interface (3-wire interface).
6. Description of the technical product improvements

The current design of hearing aids, limits the ability of an exact fitting of the hearing aid to the patients requirements, even with the help of computers and charts. The objective of this application experiment of integrating an ASIC into a hearing aid, is to compensate the hearing-loss of the patient in a much better way. The programming of the ASIC allows a fitting to the individual patients requirements, with a more flexibility than conventional hearing-aids.

The die is about 30mm² in Low Voltage 0.8µm CMOS technology. The digital part consist of 30,000 gates with a total of 120,000 transistors. The analogue part takes 13% of the total area in this chip.
The „ASIC hearing aid“ works in the following way:

The hearing-aid takes in surrounding sounds with an analogue microphone. This signal is first of all amplified in the pre-amplifier and then converted into a digital signal. This signal is split into 7-frequency bands. Each band has a gain control. Two High-, two middle- and three low -tone bands are combined into three channels. Each of the three channels has an AGCi (Automatic gain control input), which is adjustable through two independent parameters: a compression ratio control and a threshold kneepoint control. The frequency and amplification parameter of the hearing aid are stored in a configuration memory.

The next step is adding the three channels into one signal path. For further signal processing a gain-control is implemented and optionally a additional volume-control is available. For output limiting a AGCo (Automatic gain control output) with very high compression-ratio is implemented. Now the signal is converted back to sound energy by the receiver.

The hearing-aid is available with or without switch. Functionality of the switch is controlled by an on-chip configuration memory. It can be configured as volume-control or as a sequence-switch. If the sequence-switch is selected, three different programs can be used, only by pushing the switch up or down.

![Block diagram of the ASIC](image)

**Figure 5  Block diagram of the ASIC**

The programming of the configuration memory is done by software that allows to easily configure the signal processing parameters. It runs on a standard PC. Parameters are set by an audiologist on a PC screen and then transferred into the hearing aid. Computer-controlled configuration may help to improve quality by assuring optimum configuration, which can not be assured under all conditions with mechanical trimmers.

7. Choices and rationale for the selected technologies, tools and methodologies

The alternative design solutions available for the implementation of the technology were evaluated using the main criteria: costs and customised functions. Technical requirements have been low power consumption of less than 1.1 mA and small size to fit at least into a BTE hearing aid. Expected production volume is 20.000 to 100.000 pieces. Evaluated approaches have are:

FPGAs and standard components: The functions performed by the current design could not be encapsulated in an FPGA because of the limited size in a hearing-aid housing, and the same with standard components concerning the individual function of each component. A FPGA cannot be selected because it cannot contain analogue circuitry.
ASIC: The relatively high volume makes the ASIC solution economical and meets the flexibility and adaptability for the final product. The ASIC solution to perform the required functions was considered and evaluated, because e.g. of the low production time of the whole hearing-aid. The ASIC allows all the target requirements to be achieved and was the selected technology for this experiment. The mixed signal ASIC was used because of the board constraints in hearing-aids.

ASICs with analogue and digital technology were considered for the AE, using the following criteria:

- Low battery current
- Small size
- Great variety of functions
- Realisation of own specified functions

The considered digital version allows the main requirements to be achieved such as:

- Low battery current
- „Intelligent“ hearing-aids possible
- Better signal-noise ratio than analogue technology
- Better Equivalent-Input-Noise (EIQ) than conventional aids

Therefore, a digital ASIC technology was selected.

The company selected a subcontractor to develop a special ASIC which has to fulfil the specifications. The subcontractor uses different software-tools for the development of the ASIC:

- Simulation-Tools
- Layout-Tools
- Routing-Tools
- Verification-Tools

![Figure 6 Typical design flow](image)

The subcontractor proposed Thesys as foundry because of favourable conditions and prices. Major limiting factor for selection of a foundry was considerably the low volume for a special technology. If numbers are higher, many other foundries can be used.
The company used a FPGA breadboard to test the ASIC specifications. This helps the company to test and develop further features.

The final hearing-aid will be programmable with a computer and a special software using an external interface. The software development will be in Object Pascal language using a support tool for the relevant filter-coefficients. This language was used because of the graphical desktop, the visual programming and it’s 32-Bit technology. The company employs a programmer to facilitate the development of the software. The software will be included in the delivery of the hearing-aid.

8. Expertise and experience in microelectronics of the company and the staff allocated to the project

The company is developing and manufacturing hearing-aids. The company has developed 5 of the products which compose the fairly comprehensive range of hearing aid devices. The main expertise of the company lies in mechanical assembly of plastic components for hearing-aids with limited electronic. T+T has quite extensive knowledge of the electronic and acoustic systems concepts of hearing-aids, but no experience in ASIC design methods or assembly techniques for smaller size. T+T has experience and knowledge in making PCB layouts which are manufactured by a subcontractor. When starting the AE the company employs an additional engineer for the development of the software.

The objective of this application experiment is to improve the competitiveness in the market with the development and implementation of the ASIC technology into the hearing-aid sector.
9. Workplan and rationale

As a part of the feasibility study, the company developed a workplan which consists of the different workpackages and the duration in month. A correction has been necessary because of several Re-Designs. The analogue properties of the chip, especially power consumption, noise and gain proved to be very much dependent on marginal design decisions and the process, used for chip production. Therefore a number of design optimisations (re-designs), to reach specified values, e.g. for power consumption, had to take place.

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Figure 6 Planned workplan  
F = FU  S = FU + Subcontractor

The key phases of the AE were as follows:

Training

Training courses in PCB design were provided by the subcontractor to the company’s engineer. The courses enabled T+T to conduct the design and testing tasks of the experiment.

Design specifications

During this phase the detailed specifications of the ASIC were developed. The functional requirements were defined by TÜRK+TÜRK and the subcontractor proposed approaches for an ASIC implementation. The subcontractor was responsible for proposing only technologies that allow to fulfill the functional constraints. The simulation software functional specifications were developed to fulfill all the functional requirements of the product.

Hardware design

During this phase, the prototype hardware of the ASIC was developed by the subcontractor with close involvement of the company’s engineer. The engineer gained a good understanding of ASIC TÜRK+TÜRK ELECTRONIC GMBH 8/15 FUSE AE 1016
design and testing. The subcontractor was responsible for reaching the goals.

**Software design**

In this stage, the structure of the simulation and the controlling program was defined by the company’s engineer and realised by the subcontractor. The program was written and verified by the subcontractor and the company’s engineer according to the software specifications. The work during this phase has allowed the engineer to develop the necessary software skills for future projects.

**Hardware construction and test**

The PCB layout was developed and a test evaluation board was produced. The hardware was tested using controlling software developed by the subcontractor. Further hardware and software modifications were implemented.

**Functional test and software modifications**

The specifications of the final test approach were developed during this phase with the involvement of the company’s engineer. Formal testing and trials of the completed test-evaluation board was conducted by company’s engineer assisted by the subcontractor. The performance of the test-evaluation board was complied with the specifications. After this, a prototype of the ASIC was released for first production.

The company faced a barrier in the selection of an ASIC manufacturer, because of the 0.8µm technology and the low quantity. The company has to use this technologies because of the place constraints in hearing-aids. The final manufacturer was selected by the subcontractor who decided to be the one with the adequate technology and the best in price for this relative low-volume.

At the beginning of the AE, the technology barriers (Section 11) were the main problem of the company which resulted in a delay of finishing the specifications. This first delay resulted in a steady delay in further projects which consist on the specs (e.g. Design, manufacturing, testing).

At the end of the design phase, problems with the size of the ASIC occurred, so that a re-design was necessary. As a result, the first ASIC production was delayed. And according to this, the testing started with a delay.

The first re-design was necessary because of problems with the metal layer. After the 1st re-design, several technical problems occurred, such as:

- Battery current draw to high (4.6mA instead of max. 1.1mA)
- Re-work of the DD-converter
- EQN to high (30dB instead of max. 24dB)
- Operation current to high (<1.6V instead of 1.1V - 1.3V)
- EEPROM communication was insatiable

This shows the company, that it is necessary to plan more re-designs, especially for analogue parts or features. It also enables the FU to implement further features in the ASIC, but any change may cause another re-design later on and has to be considered very carefully. Since a re-design often causes significant costs, it is very important to agree on responsibilities.

The lessons learned are that the time for specification, design, production and testing has to be planned more generously. And that several re-designs have to be planned.

**10. Subcontractor information**

The company has selected subcontractors to support the development of this in-house embedded ASIC design capability. One subcontractor was selected for the design of the hearing aid DSP-chip. In addition to the design of the circuit, packaging and assembly was a major problem, which had to be solved. In order to use the chip in a hearing aid, the overall size has to be as small as possible. Therefore the TÜRK+TÜRK selected one design-house and a specialist for micro-assembling as subcontractors. The subcontractors were selected for the following reasons:
• Prior experience of developing ASICs, especially in low-power design
• The ability and agreement in the objective of transferring knowledge via a co-operative development process
• As a local subcontractor the company is able to provide technical support throughout the introduction of the design to manufacturing
• Cost effectiveness
• Vicinity to the FU and between the subcontractors
• Subcontractor (Micro-Assembler) was already known by FU
• A contract was made between the FU and the subcontractor. This contract includes one redesign and further assistance in future problems and questions. Other terms of this contract are:
  • Contractual co-operation
  • Guarantee and liability
  • Rights
  • Remuneration
  • Duration of contract and termination

First user and subcontractors agreed on a contract with clear responsibilities. The subcontractors were responsible for presenting only design alternatives that would allow to reach the functional objectives. TÜRK+TÜRK was responsible to define the functional requirements according to a list of parameters, requested by the subcontractors. The subcontractors were responsible for correct operation of the chip according to the specification, which the parties agreed on and have to pay re-design costs from their budget. The first user learnt that most design companies plan at least one redesign and consider it in their budget, but try to offload the responsibility to the customer, especially if design decisions are taken by the customer.

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

There were several barriers that have prevented the company from adopting digital technology to improve its products and compete more favourably in the market place. These barriers included:

Knowledge barriers
The company knew that there is a need to improve its products due to the increased competition in this area. The company also realised that continuing with the existing products will limit its ability to grow. In addition, there was an understanding that the required solution lies in digital-technology. However, the company did not have the answer to many fundamental questions including:

• What are the appropriate improvements?
• What are the possible solutions?
• What technology is suitable?
• Where can answers be found?

Psychological barriers
Similar to many smaller companies with low level of expertise in ASIC technology, T+T faced several psychological barriers. There was a respect for any technology more advanced than conventional components, PCBs and Thickfilm-technology and a strong perception of high risk. This belief that adopting a new technology is risky, stems from the fact that the company had a feeling of technical inadequacy. As a result the company’s natural approach to improve its position was to
consider other solutions, such as better marketing-, mechanical-, and design-improvements, rather than a new technology.

**Technology barriers**

The limited knowledge in ASICs has manifested itself in technology barriers that have contributed to the overall difficulties of introducing a new technology. The company was not clearly able to choose an appropriate technology to solve its problems and even when the ASIC solution was selected there where additional technology barriers that had to be addressed including:

- Limited technical management capabilities
- Lack of expertise in digital technology
- Lack of software knowledge for filter-simulations

**Financial barriers**

Although financial barriers are not the most important barriers for the company, but they tend to be significant for a small company like T+T. Any investment in research, development and training can affect production and sales because resources have to be diverted away of the main business activities. Therefore, there was a strong perception at the company that the necessary technology step can have significant financial implications and represents a high risk. The financial barriers coupled with the limited knowledge of technology costs resulted in an amplification of the psychological and financial barriers.

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

The process of overcoming the barriers facing T+T in adopting the new technology started following the initial contact with the subcontractors. During this process the company was provided with training by the subcontractors on the following topics:

- The available ASIC technology options and their merits
- The economic and business implications of adopting the new technology
- Technology selection process

T+T conducted a study into the improvement of hearing-aids. This study has resulted in the selection of ASIC technology and covered the technical and economical aspects of adopting the technology. The study was documented in the form of the FUSE proposal for this application experiment.

The initial training, study and the preparation of the FUSE proposal have allowed the company to address and overcome some of the barriers listed in section 11, especially the knowledge barriers, and some of the psychological barriers.

In conducting the AE, T+T has made available for the duration a small development team comprising two electronic engineers and a programme manager to ensure that the knowledge is captured efficiently by the company. These people form the core team for the application of this technology. The selection of an experienced subcontractor and the decision to undertake the development at the company’s site and the subcontractor’s premises, have ensured a continuous transfer of all the various technical expertise necessary for the adoption of the new technology.

Dedicated training in the areas of IC and PCB hardware development, programming and the use of development tools was provided for the company’s engineer at an early stage of the AE to ensure the knowledge acquisition process can be effectively undertaken. During the experiment the hardware and simulation-software development was undertaken by the subcontractor, with T+T providing with acoustic advice, pre-amplifier design and manufacturing and the review support service.

An advantage of this joint development is, that issues relating to the necessary production planning and manufacturing methods to deal with the new technology in this environment will be undertaken by the programme manager. This capability forms an aspect of knowledge development in the company and the full industrialisation of the final product.
13. Knowledge and experience acquired

This AE demonstrates that acquiring the knowledge and skills required to adopt ASIC technology can be achieved from a lower starting point. T+T has expertise in the design and manufacturing of products utilising standard components and PCBs. The company did not have any managerial or technical expertise in ASIC-based applications and development projects. Therefore, a profound understanding of electronic design principles is a sufficient starting point to embark on an ASIC-based project with training and assistance from a third party.

The company’s knowledge acquisition process started during the preparation of the FUSE proposal. The preparation of the proposal, which included a feasibility study, allowed the company to start the knowledge transfer process at an early stage. This process has continued during the AE with the company acquiring knowledge from the subcontractor, and gaining expertise during conducting the tasks of the experiments.

As a result of the work conducted during the AE, the company has acquired skills and gained knowledge in the following areas:

- Technical management of ASIC based products
- Product specification and system design of ASIC products
- Embedded software specification and design
- Fault detection and isolation methods
- ASIC manufacturing and test methods

After completing the AE, the company has two more electronic engineers than at the beginning of the AE.

14. Lessons learned

During the progress of the AE, the company has accumulated a wide ranging experience covering managerial, business and technical issues. Amongst the important lessons learned during this AE are the following:

Barriers:

At the end of this AE, the company’s experience indicated that there were no significant real barriers to introducing ASIC technology into hearing-aids. With hindsight, it is possible to conclude that most of the barriers were perceived, but the lack of knowledge coupled with the fear of any new technology were the main reasons that have prevented the company from attempting to introduce the technology at an earlier stage. The company believes that beside of all the barriers listed in section 11, the knowledge and psychology barriers were the most significant. The technology barriers were not significant because those can be overcome by working with a subcontractor and attending training courses. The company has gained a great deal of confidence in dealing with new technology and believes that it can find the sources of information for any future development. Therefore, the company will not find itself in the future in a position where it cannot improve its product due to the lack of knowledge of the appropriate solution.

Technology:

One of the key reasons for the success of the AE was the selection of the correct technology to improve the product. ASIC technology allowed the company to implement all the necessary improvements, and to plan for exploiting it in other products. The technology was also appropriate for the technical capabilities of the company and did not represent an unreasonable technology step. In addition, it was the right technology from a risk analysis viewpoint. The expertise gained during the AE will allow the company to rely mainly on its in-house resources for future ASIC-based projects and without great need for third party assistance. The company believes that ASIC technology can provide an appropriate technology solution to a wide range of companies, especially those with little experience in electronics or those starting from a low level in the IC-technology ladder.
difficulty that has faced the company is in developing the software skills and applying them to control the hardware.

**Industrialisation:**

T+T was aiming to introduce the product into the market immediately after the completion of the AE. Therefore, it has considered the industrialisation of the improved product during the AE. This process has implications on the company's manufacturing, testing and marketing arrangements which have to be completed before the improved product can be introduced. The lessons learned are that these factors should be taken into account as early as possible, starting with the feasibility study and specifications development stages. This is the only way to avoid having an unnecessary gap between the completion of the prototype testing and full volume production. T+T has managed to secure orders for the new product even before the completion of the AE, and is expected to produce the units for these orders in the few weeks following the AE. The consideration of the industrialisation issues during the AE is very important because it may influence many of the design and implementation decisions.

**Benefits to the company’s business:**

The adoption of ASIC technology has resulted in several benefits, especially at the economic level. The new technology will allow the company to become more flexible and competitive as it introduces ASICs into its products. In the past, when the need has arisen to improve competitiveness, the company’s approach was centred on marketing or mechanical and aesthetic improvements. This approach did not provide the company with a strong competitive edge. The lessons learned from this AE is that product improvement through ASIC solutions can be easier and cheaper to implement, and will clearly enable the company to compete more favourably.

**15. Resulting product, its industrialisation and internal replication**

The process of completing the AE facing T+T in industrialising the product starting by choosing the right manufacturer for the final ASIC. The key points in this selection were:

- Financial and cost aspects
- Technical capability
- Delivery time and capacity
- Vicinity to the company’s site

T+T selected, with the support of the subcontractor, a manufacturer who is able to fulfil the specifications and who has the technical experience in the appropriate technology.

The training at an early stage of the AE ensures that the knowledge and skill acquisition process is more effectively. The joint development, between the subcontractors and T+T, is of the advantage that a continuous transfer of knowledge is ensured to both sides. As a local subcontractor the company is able to provide technical support throughout the introduction of the design to manufacturing and in future problems.

The mechanical development, like housings, prints and tools is done by the FU. The plastic housings with it's tools take the company 12 month for development and production. The packaging needs about 1 week.

The company made first production test without implementing the chip. For this a preliminary housing and PCB were used to verify the manufacturability and production costs with the available assembly resources. The results show that the prediction of the production time is in the projected limits.

With availability of series chips, the product is planed to be on the market in early 1999, but marketing activities readily started. Production tests were intensified with prototype chips to assure correct handling and quality measures. Usability of the hearing aid in conjunction with the programming software has been verified in field tests.

The versatility of the ASIC allows it's use for different types of hearing aids. However there are already ideas for even more sophisticated DSP-functions, in order to strengthen our position as
A decline in sales for the conventional hearing-aids can be reversed by the development of a more advanced and flexible product, enabling the company to offer a technical solution which cannot be achieved with the current used technology. The new technology opens the high-end market for the FU. The broader application field of a digital hearing-aid is considered a significant market-advance for this industry, and represents an important technical improvement over the company’s current position. The technology allows the company to participate with other competitors in the world market. The world-market needs hearing-aids not only to "hear" but to "understand".

The new developed ASIC, especially the final product has the potential to meet the world market needs, and the company expects to establish marketing and manufacturing agreements in several countries. The product will be introduced in spring 1999. These factors mean that by 1999 T+T ELECTRONIC sales will increase by 24% over the 1997 figures. Figure 8 shows the actual (1997) and the projected (1997-2002) sales of quantities of conventional and new hearing-aids. The changes are relative to the 1997 business sales of the product.

The manufacturing costs of the new product are equal to the conventional existing hearing-aids. Furthermore, the new hearing-aid will allow the production time to be reduced. These facts and the higher flexibility of the new product, will result in a higher selling price which will increase the margin of the FU. For the 12 months warranty, which is provided free with the products, no saving of the product costs can be achieved.

The increase in sales of the new product will allow the company to increase its profit in 1999. The payback period will be 2 years after introducing the product in the market. The product lifetime is about 5 years, the return on investment is about 300 %. The time to market is about 1 year.

Figure 9 shows the relation between the increase of sales and the change of turnover because of the higher price of the improved product.
TÜRK+TÜRK ELECTRONIC also manufactures a range of conventional analogue hearing-aids. Those aids will be, in the future, mainly exported to emergent countries. Whereas the new product will be sold in the main markets (GER, USA and JPN). The company also expects a increase of the world-wide potential of 25%, which allows plenty of room to expand. The company expects to increase their share of the market up to 15%.

The world-wide potential of 3.5 Mill. sales per year gives the company plenty of room to expand. The company estimates, that the new development could double the world-wide sales to 100,000 units in the next 3 years. As a result the company staff expands to 100 people, which means a job creation of 30%.

17. Target audience for dissemination throughout Europe

T+T operates in a market of consisting of many small and only some big suppliers. In Germany the company's market assessment indicates that only one of its competitors currently uses ASIC products to meet customers requirements. This AE will therefore provide an experience of special interest to smaller companies throughout Europe, and will demonstrate how the assimilation of an ASIC design capability can be undertaken with relatively low risk and result in a commercial benefit to their business. This AE will also be of interest to small companies currently capable of developing discrete PCBs, but are unable to commit themselves to ASIC technology, as was the case with T+T, because they are unable to devise appropriate knowledge development strategies without jeopardising existing customer service relationships.

The dissemination of the development of subcontractor relationships and formal contracts that results in knowledge transfer from the subcontractor into the company will be of special interest to the small companies audience. The knowledge to be disseminated will include data on the knowledge acquisition process, impacts of the technology on the skill development of related functions (e.g. production test), assessments of the benefits of improved product reliability, comparisons and contrasts in the management of hardware and embedded software projects, enhancements of site surveyor and marketing personnel awareness of technology options, and the commercial gains experienced.

In general the results of this AE will be of interest to companies operating in the high-end hearing-aid market.