FUSE

Demonstrator Document
AE 1707

Braille terminal:
FPGA enhances reliability and reduces cost

Abstract

ALVA, a 14-year old, 40 employees-company, develops, produces and sells PC products for Braille and speech oriented machines for blind and visually impaired users. The major product is a Braille terminal, which connects the PC and the printer. This terminal translates the output on the computer display into Braille characters, which can be read on a Braille printer output device.

ALVA is for 13 years active in the Braille market. The products are defined, developed, and sold by ALVA. ALVA does have all the skills needed for this process. The knowledge of the needs of the blind user is present in the organisation. The technology knowledge needed for development and production is present is the R&D department. Market knowledge and the sales outlet are present in the sales organisation. Last but not least ALVA installs and maintains the equipment in field, which gives a feedback from the end users of the products.

Before the experiment, the electronic technology used in the company was based on standard components on printed circuit boards. The requirements of miniaturisation and low power consumption for portability reasons were the main reason for the AE.

The main objective of the experiment was to improve the reliability, improve features and functionality, and improve the performance of the communication ports so that they could communicate with modern personal computers. Price performance ratio needed to be increased so that an increased share of a stable market could be achieved. The existing ALVA Braille terminal communicates in a relatively simple way through the Centronics port of a PC. In order to develop a highly advanced and competitive terminal two FPGAs have been designed. The components have been implemented with an enhanced hardware communication protocol for communication between the parallel port of a PC and the ALVA Braille terminal.

Therefore a more reliable ALVA Braille Terminal (ABT4) prototype has been designed, manufactured and tested. The previous version of the ALVA Braille Terminal (ABT3) was not sophisticated enough to function smoothly with the latest PC's, which have increased speed of the printer port. As it proved impossible to increase the communication speed of the ABT3 terminal with the current microprocessor technology, ALVA adapted new FPGA techniques and a highly sophisticated method of specifying and designing electronics. After a period of nine months the application experiment was finished and consequently approved prototypes were released. The total cost of the experiment was 60 k€ of which 31 K€ was the FUSE investment. Further costs to get the product to market were approximately 100 k€, which included redesign prior to production. The overall payback period of the investment is anticipated to be 2 years with a return on investment of 300% over 6 years of sales.

The main lessons learned are that intensive support by a subcontractor pays off, the effort put in the specification phase will paid back in the design phase and it is recommended to make the design of the FPGA synchronous. It was also realised that technical resources can adapt to FPGA design quite easily.

Keywords

FPGA, Verilog, SMD, Braille terminal, computer peripheral Asynchronous design.

Signature

3 1420 555 1420 1 3210 2 33 NL

1. Company *name* and address

ALVA B.V.
Leemansweg 51
8627 BX Arnhem

2. Company size

A blind man, who aimed to realise an improved version of the then existing Braille terminals, founded ALVA in 1984. Fourteen years later ALVA has grown into a company that employs 40 people, 5 of which are responsible for the administrative tasks; 8 are involved in Marketing & Sales; 10 handle Support & Services and 6 the production and maintenance division.
Finally 10 employees are in charge of the R&D department; besides the Manager R&D, the group consists of 7 software engineers and 2 electronic engineers. The total company's turnover in 1998 was about 6.4 million Euro. The blind founder is still leading the company as the president.

3. Company business description

ALVA develops, manufactures and sells equipment for blind and visually impaired users (ProdCom code 3310). This equipment allows access to the PC through Braille, speech or magnification or a combination of these media by using graphical user interfaces of modern computers. The main product is the ALVA Braille terminal and the (graphical) screen-reader software (OutSPOKEN, InLARGE). A Braille terminal is a hardware device that converts textual information into refreshable Braille. One Braille cell contains 8 dots, which together display one character. A Braille terminal contains 43 or 85 of these Braille cells. The screen reader software captures all the information of the PC screen and converts this into Braille information or electronic speech.

ALVA provides also training and (user) support and service. In The Netherlands, the equipment is sold directly to the end-user. The sales department is also situated in Arnhem. Four sales people are responsible for selling direct to end-users. In the market of blind also financing is very important. The sales people are highly educated in funding rules for blind people. They are filling in the application etc.

In other parts of the world, among which the European countries, the products are distributed through a world wide dealer network of more than 30 dealers. 4 Sales people maintain this network. This department is responsible for all the sales outside the Netherlands. Their main task is to support the dealers to sell the products. This support includes marketing trade shows etc.

There are three categories of stakeholders: the visually impaired users; the insurance companies, who finance the purchase; and the institutes, who advise and train the users. Each part taker is of equal importance to the decision making process.

The R&D division that is staffed with 10 engineers certainly contributes to the status of ALVA as a continuously innovating company that adapts the latest technologies. The objective of this Braille expertise is to become the world market leader in Braille terminals and screen reader software for visually impaired users.

In this Application Experiment three ALVA people were closely involved: a hardware designer; a software specialist, and the R&D manager.

4. Company markets and position before the AE

ALVA has an in depth knowledge of the market of Braille terminals and the world-wide use of Braille cells. In the near future, the market for Braille terminals is not likely to grow, mainly caused by the "frozen" budgets of the insurance companies and institutes. Unfortunately for the users, for there is a growing need and demand on their side.

Due to the availability and lower price of software products for speech and display enlargements, these markets are growing fast. However, speech is very volatile and requires a "fast consumption" of the information, whereas Braille can be read at a speed which suits the user.

60% of today's turnover is realised by the distribution of Braille Terminals. The table below gives an overview of the ALVA competitors. As is clearly shown, ALVA is one of the market leaders with a world wide market share of about 11%.

Company	Country	Market Share	Price indication
Papenmeier	Germany	11%	6.500
ALVA	Netherlands	11%	6.000
Baum	Germany	11%	6.000
TSI	USA	10%	6.000
Tieman	Netherlands	8%	5.500
Frank Audio	Germany	8%	5.000
Others		41%	

Table A: Overview market Braille terminals

The average end user price of the ALVA Braille terminal (ABT3) is 6.000 €. The average margin of the Braille terminal is about 50%. The electronics investment is about 5% of the total cost of the Braille terminal. The market shows a price fall of the Braille terminals. However, the market potential will remain stable.

The differences between the products on this market are minor. The essential aspects for the new product are both its functionality and quality. ALVA takes into account that the price of the new product may be higher when these important aspects have been well implemented.

On the other hand, ALVA is prepared to take the risk; for it is exactly these essential items, that distinguishes ALVA from their competitors.

Competition	Country	Employees	Cells (x1000)
Papenmeier	Germany	40	35
ALVA	Netherlands	40	30
Baum	Germany	50	30
TSI	USA	60	25
Tieman	Netherlands	50	20
Frank Audio	Germany	50	20
Tieman	Germany	20	15
EuroMIW	France	5	10
Blazie	USA	25	10
KGS	Japan	10	6

Table B: Overview of market competitors

In the following table the sales numbers over the last years are given. It is important to know that the ABT3 will remain available on the market as a low-cost terminal, which still can be connected to several PC's.

ALVA Sales History of Braille displays				
Type ABT	*1995*	*1996*	*1997*	*1998*
340	260	213	201	195
380	178	114	164	157

Table C: Sales History (units sold)

5. Product to be improved

The existing ALVA Braille terminal (ABT3) is a hardware device that displays textual and graphical information shown on a PC screen in refreshable Braille. This product enables blind and visually impaired users to profit from modern Information Technology (IT) equipment like PCs. The ABT3 is connected with the PC through a standard available computer port (serial or printer). The PC software picks up the PC screen information and stores it in a database (off-screen-model). The end-user pushes the buttons on the ABT3 in order to control the part of the screen he wants to 'see' in Braille on the ABT3 Braille Terminal.

The Braille Terminals are generally used in combination with a laptop and for that purpose, they are equipped with a rechargeable battery pack. It will be evident that power consumption is one of the important aspects of such a terminal.

The performance of the current interface is consuming all the microcomputer capacity. The market requirements for new functions also require more computer capacity. The application of the FPGA enables the possibility to use the computer for features instead for the relative simple time consuming interface protocol.

The physical characteristics of the parallel interface are well defined by the computer industry. However the protocols used by these interfaces are mostly standardised or vendor propriety. The flexibility of the FPGA in combination with the possibility to implement rather complex sequences makes the FPGA an ideal candidate for this purpose.

The production cost is not very dependent on the FPGA choice. The FPGA is only used in the interface part. This interface is about 5 % of the total production cost.

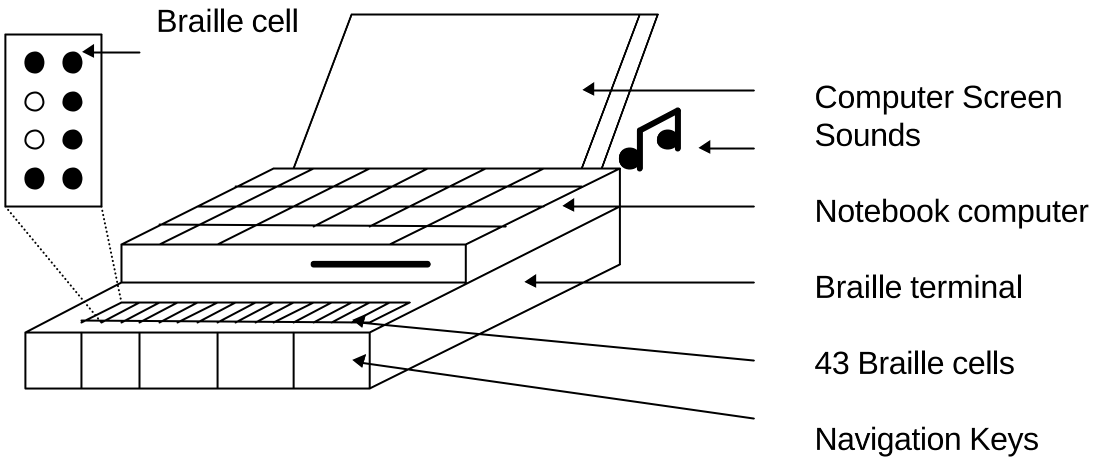

Figure 1 Braille terminal and Notebook

The screen information of the Personal Computer is intercepted and captured with a special software program. This program called screen-reader, sends textual information to the Braille terminal, which contains 43 or 85 Braille cells. One Braille cell is built up with 8 dots, which together display one character. The Braille terminal is connected with the computer through the standard printer port or serial port. The Braille terminal displays the textual information in refreshable Braille. The user can navigate on the screen by using the keys on the front of the Braille terminal. He can move the text cursor to a position by using the small switches that are placed above each Braille cell (Touch Cursor, patented by ALVA). The functionality of these switches is identical to the left button of the mouse. Instead of moving the mouse, the user touches the switch just above the character, where he wants to insert the text cursor. The Braille terminal can generate sounds for user interface feedback (e.g. on/off switch).

The technology that is used in the current ABT3 Braille terminal:

- Piëzo Braille cells: The 8 dots of the Braille character are realised by piëzo elements
- A voltage of 260 V is needed to activate the element
- Hitachi H8 micro controller
- Standard CMOS digital IC’s and memory
- DC/DC converter: 9 Volt to 260 Volts
- Simple 2 layer through holes PCB

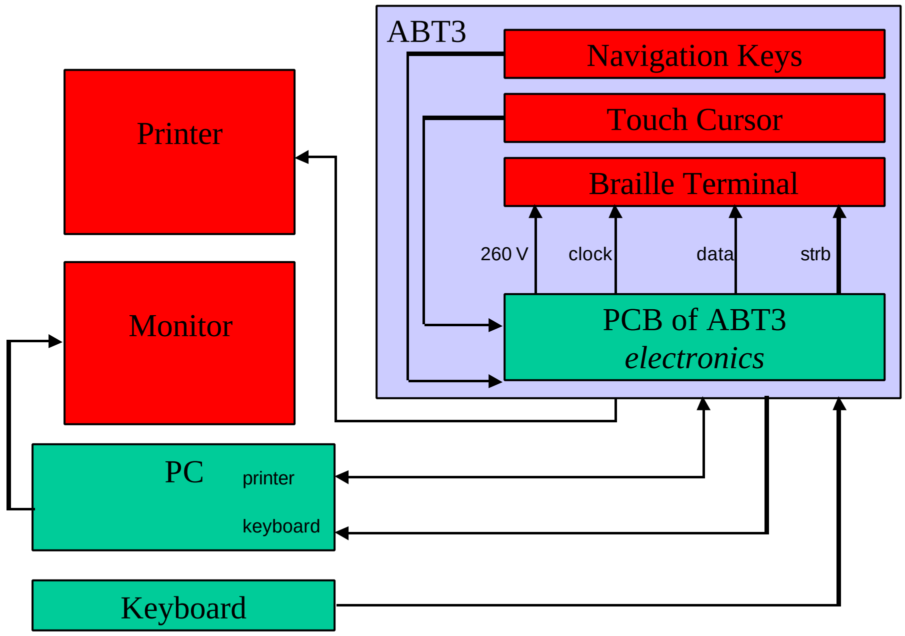

Figure 2 Functional block diagram of the ABT3

In most of the cases, the Braille terminal is connected with the parallel printer port of the computer. The printer can be connected to the Braille terminal, which routes all the print jobs through to the printer. The advantage for the user is that no extra hardware is needed to connect to the Braille terminal. The disadvantage of using the printer port for communication is that it is not standardised. This lack of standardisation is a bottleneck for all manufacturers of connectivity devices. For this reason, ALVA had to define its own parallel communication protocol. Also, the hardware level of the printer port is inadequately defined. This results in technical difficulties for the parallel connection, which will consequently not function in all circumstances. The Braille terminal hardware must be able to handle all combinations of high and low speed computers and printer ports. Currently there are PC's on the market, which have interfacing problems with the ABT3 Braille Terminal.

Figure 3 Picture of the Braille terminal integrated with Laptop PC

6. Description of product improvements

Instead of introducing incremental design changes in order to tackle the interface problem for every single type of new PC, ALVA decided to do a major redesign.
The new Braille terminal (ABT4) has some major improvements compared to the previous terminal (ABT3):

1. Improved parallel communication of the ALVA Braille Terminal: The FPGA hardware implementation of the protocol shows an important increase of the speed performance compared to the micro-controller implementation of the ABT3. This eliminates the current capacity problem of the ABT3, which can not handle the latest high-speed printer ports.
2. DTC: Double Touch Cursor on the Braille terminal (Patent Pending). Two small switches will be placed above each Braille cell. Nearly two hundred switches have to be scanned. The ABT3 hardware can handle hundred switches, which was the maximum that could be handled by the microprocessor. Where the Touch Cursor of the ABT3 only imitates the left button of the mouse, the second switch is needed to imitate the functionality of the right button of the mouse.
3. Built-in speech synthesiser. An extra serial interface will be added to the design. This speech synthesiser will, by the way, not be realised with the FPGA-technology, but with existing standard components.
4. A four layer SMD PCB will be used for the ABT4, because the FPGAs are only available as SMD components and some other devices are becoming obsolete in their current through-hole packages.

The ABT4 distinguish from the Braille terminals of the competitors by:

Higher quality: Better parallel communication, less defects.
DTC: Double Touch Cursor (Patent Pending), with a tremendous ease of use.

1. Integrated speech synthesiser.
2. Re-loadable firmware.

The component that has materialised from the experiment is an FPGA that replaces standard electronic components and provides additional functionality. In one of both FPGAs the scanning of the DTC has been implemented, whereas the hardware of the other FPGA is equipped with the improved parallel communication.

In case of a printing job, the FPGA sends the information from the parallel port of the PC to the external connected printer (route through). In all other cases, the FPGA handles the low level of the parallel ALVA communication protocol. The data from the PC is analysed, checked, and moved into the SRAM. As soon as a data block has been successfully transferred, the FPGA will signal that the information is available in the SRAM. The micro controller can then read this data and put the selection that must be sent to the PC into the SRAM. The FPGA will transmit the data to the PC by generating the correct signals on the parallel port of the Braille terminal.

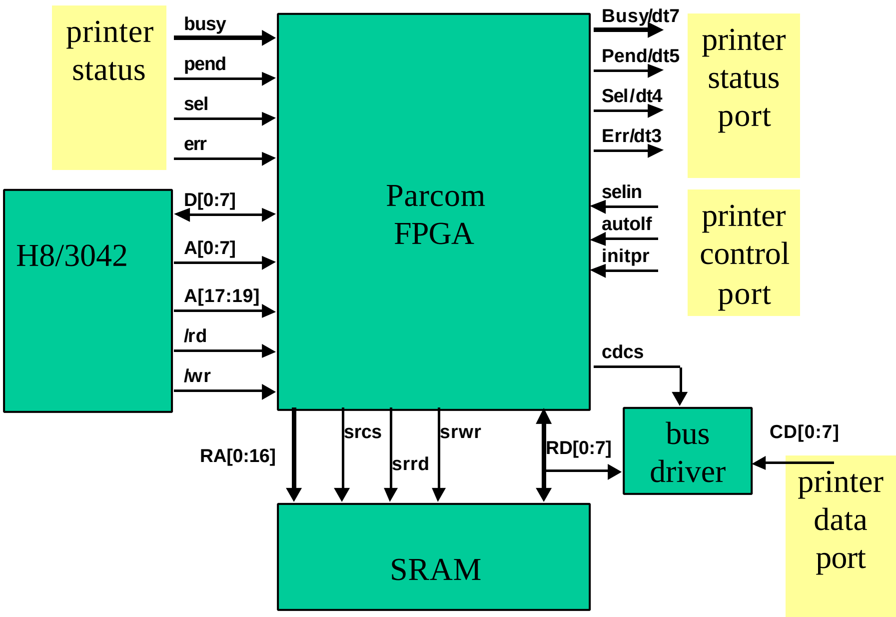

Figure 4 Functional block diagram of the communication FPGA

7. Choices for the selected technologies

ALVA chose to specify the system with the Ward-Mellor method, because of its easy-to-use systematic top-down character, which gives a good insight in the complexity and a good partitioning of the system. The old-fashioned approach of writing documents (in English or Dutch) is too ambiguous for specifying complicated designs.
There were two options in the use of a HDL language VHDL or Verilog. ALVA opted for the Verilog HDL-language for the easier to learn and use capabilities. And the Verilog software supported by Quicklogic was much cheaper then the VHDL software.
Since ALVA plans to do one major update of their products every three years, tools need to be depreciated over this project. Therefore, it is not very realistic to buy a sophisticated simulator and synthesis tool. Keeping that in mind ALVA chose to use just the basic software, which is supported by Quicklogic.

In the current ABT3, the communication is handled by a combination of standard logic and a microprocessor. This results neither in the required speed nor in the required low power consumption. As there is a lack of new standard components, which can meet these requirements, a new technology must be adapted.

ASIC-technology could have met the requirements, but both the developing time and the costs were not in pace with the low-volume production (< 1000 per year) that was required. If the ASIC design had not been right the first time, this would have resulted in even longer development time and higher costs.

FPGAs were the answer, as they could meet the requirements and remain within the development cycle, which is by far shorter, then the one for ASICs. Even if a redesign would be necessary, it is relatively simple and inexpensive to implement the changes. ASIC-technology would cost 20 k€ to 50 k€ extra for the NRE and development time was expected to increase with three to six months compared to the FPGA option.

The choice to use a FPGA instead of the application of standard components has two reasons.

First, the size of the standard products is rather big. The FPGA equivalent of the implemented interface is about 15 times bigger than the FPGA.

Second, the power consumption of the FPGA is less than a solution based on the standard components.

A quick scan was done on several existing FPGAs of different vendors in order to decide which FPGA would be the best solution. Selection criteria were: the price, speed, power-consumption, copy protection, appropriate gate count and pin count.

Two main reasons to choose for Quicklogic FPGAs were their low-power consumption and the good price- performance ratio. One small disadvantage had to be taken into account; during the development cycle, they can be programmed only once.

Being able to cope with this new technology, still a design methodology needed to be chosen. Either the old fashioned schematic captures or a new HDL language could be used. Schematic capturing proved to be inappropriate for design of this kind of complexity.

8. Expertise and experience

ALVA has a thorough insight in his market and its users. According to the market structure in the Netherlands, where generally health insurance companies finance the equipment, the products are sold directly to the end users. In the other countries, the products are distributed through a world wide dealer network.

The staff of the R&D department is mainly specialised in the field of software engineering and hardware design. The manager of the R&D department has a Master's degree in electronic engineering and 12 years of experience in the field of electronics and software engineering. Besides his technical capabilities, he is also skilled in the management of R&D departments.

The seven software engineers have a Polytechnic degree in software engineering and have 10 years of experience in developing high and low level PC software programs.

The two electronic engineers have both a Polytechnic and Master's degree in electronics, and 15 years of experience in designing digital and analogue electronics.

The company as a whole is well known for their experience in designing micro-controller applications, DC-DC converters, and printed circuit boards. All these products are designed with off the shelf components mounted on printed circuit boards.

ALVA is experienced in handling simple PCB production of small quantities on annual basis.

Since the company was founded, ALVA has worked on developing an extensive relationship with all the decision-makers in this sector.

9. Workplan and rationale

The Braille terminal is the main ALVA product. In order to stay competitive in the future it is essential for ALVA to have all the knowledge of the Braille terminal hardware in-house. ALVA therefore decided to design the FPGA in-house. The decision was made to build up the experience by following a tutorial course. After this course, the design was started and further experience was built up in this way. The distributor of the Quicklogic FPGAs was requested to give only some limited support.

ALVA had expected that just a minimal support was needed to successfully complete this project and to assure that all the expertise was gathered within the company.

In the following an overview of the planned and actual tasks and sequence is given.

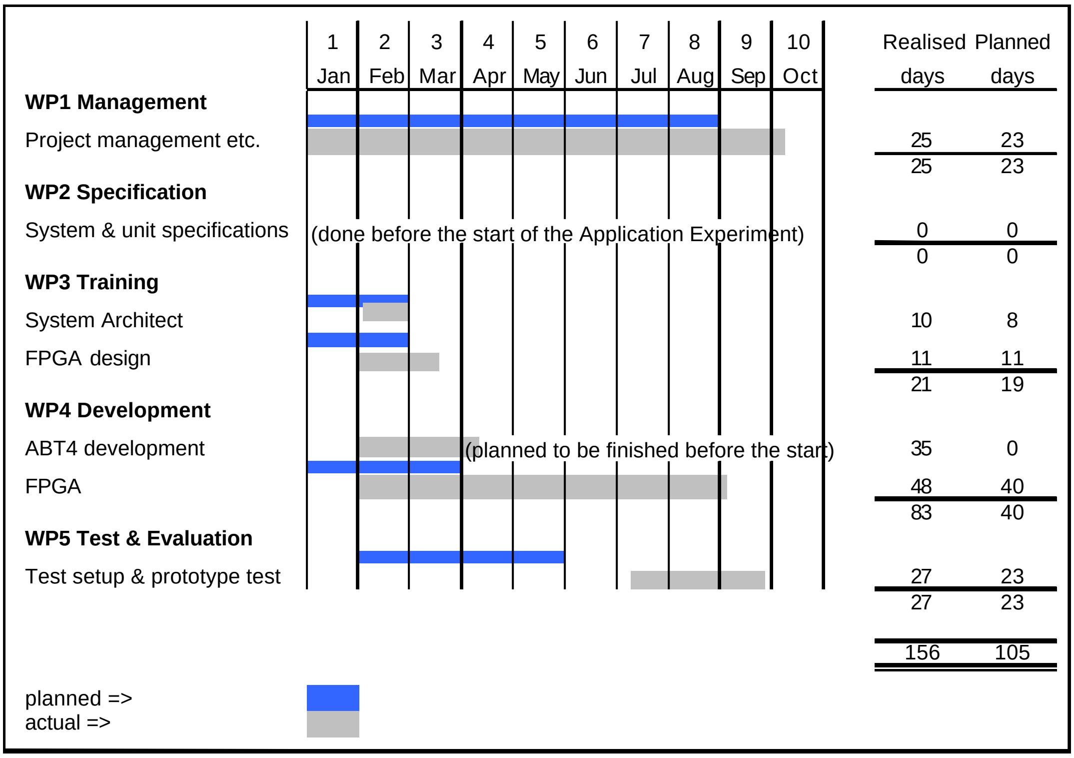

Figure 5 Workplan (planned and realised)

Role of the subcontractor

The role of the subcontractor was limited in the project and the subcontractor charged no costs for the support given.

The subcontractor was the supplier of the FPGAs, as well as the simulator and synthesis tools, and did give support by a Field Application Engineer. They also gave support at the tutorial training and on the job support whenever a bug or limitation was found and the first user could not solve it.

Although, this was ad-hoc support, there was indeed knowledge transfer from the subcontractor to the FU.

By the nature of the subcontractors involvement, the effort spend by the subcontractor was not recorded.

The specification phase was divided in three parts:
A functional specification of the whole product,
A specification of the communication protocol,
From these two specifications, a specification for the FPGA design was made.

The design phase was divided in three parts:
Training was needed in order to get some knowledge of the technology and the related tools,
The overall schematics of the PCB, which was done in parallel with the FPGA design,
And of course, the FPGA designing itself.

The test phase was divided in two parts:
First, a test plan was carried out to debug all parts of the design,
As a follow up the production tests were done.

The original plan was largely followed.

The main difference with the original plan is the time needed to design the FPGA. The main reasons were:

Unknown limitations of the Synthesis tool. The designer spent a lot of time tracking the limitations of the tool. A more expensive, but more efficient tool with fewer limitations might have resulted in less effort to rewrite the Verilog code.

Unknown bugs of the Synthesis tool. The tool had also some bugs, which were not always directly discovered as such and a lot of effort was used to find out a workaround. Sometimes the Field Application Engineer or the distributor had to solve the problem.

Debugging of an asynchronous part of the FPGA design. The designer put an asynchronous signal into a synchronous state-machine causing an inconsistent failure of the system. It took a long time to discover what was really going wrong. Finally, the designer found out that the design worked after first synchronising the signal.

Testing the production is very important for ALVA, for their name stands for quality. The products are tested in-house on an In-Circuit Tester in combination with dedicated manual written software test programs. This was still possible for a system of this complexity and it proved to be the cheapest solution.

The following table shows the planned and actual costs.

Project Costs (K€)	ALVA		Subcontractors		Total	
	Planned	*Actual*	*Planned*	*Actual*	*Planned*	*Actual*
WP1 Management	6.440	5.888	**-**	**-**	6.440	5.888
Project management etc.						
WP2 Specification	**-**	**-**	**-**	**-**	**-**	**-**
System & unit specifications						
WP3 Training	4.200	4.282	**-**	**-**	4.200	4.282
System Architect						
FPGA design						
WP4 Development	12.200	19.035	**-**	**-**	12.200	19.035
ABT4 development		24.620				24.620
FPGA						
WP5 Test & Evaluation	6.404	6.058	**-**	**-**	6.404	6.058
Test setup & prototype test						
Total	**31.280**	**59.883**	**-**	**-**	**31.280**	**59.883**

Table D: Overview of planned and actual costs

The variances in the costs can be explained as follows:

First of all ALVA was convinced to be experienced enough to introduce a new technology with only a limited external support. The consequences were underestimated costs and time span needed to develop the prototype. The same optimism was the basis for the decision to use the new development-tools right from the start to design a new product.

During the experiment, additional reasons for delay were encountered. At the start of the FPGA design, ALVA encountered some hidden bugs in the synthesis tools. Although a workaround for this problem was found, it had caused an unexpected delay. Moreover, during the experiment, ALVA was confronted with a large number of defective PCB's due to the change to fine-pitch technology. Therefore, the production had to be optimised.

The main lesson learnt in this experiment is to become familiar and experienced with new tools and technology on a test/demo design, rather than to use a new prototype product to learn from mistakes.

10. Subcontractor information

SEI Benelux

SEI is a distributor of hardware components (Micro controllers, FPGAs and DSPs) and software tools.

SEI Benelux has chosen because a long relationship with ALVA already existed with the predecessor Rodelco that sold hardware components for many years and is renown for the outstanding support to their customers particularly with FPGA and gate arrays.

There was no support contract. The support was given on the basis of a purchase order, without any clause on IPR or penalty. A special contract was not considered, since the role of the subcontractor was limited but crucial for the progress of the project.

11. Barriers perceived

ALVA encountered the following barriers in the initial use of the new technology:

1. Adopting a new design methodology. The trial-and-error method was no longer sufficient.
2. Introducing a new technology incorporated a lot of uncertainties and risks.
3. New design tools had to be used. The limitations and bugs of these tools were unknown.
4. Estimating costs and time span is almost impossible for a company, who is introducing a new technology.
5. After the first production batch of PCB's, ALVA was confronted with a large number of defective PCB's. The soldering of these fine pitch components popped up as the bottleneck. Therefore, the production had to be optimised.

12. Steps taken to overcome barriers

The technology and production of FPGAs has been new for ALVA. To overcome the barriers and arrived with a solid state-of-the-art product, ALVA has developed the following strategy:

- Choose a good FPGAs vendor with a good support,
- Organise training in co-operation with this vendor,
- Develop a FPGA design,
- Produce a prototype,
- Learn form the mistakes,
- Develop a real product,
- Release the product.

1. ALVA replaced their trial-and-error method by introducing the Ward-Mellor method for specifying the design. This method is implemented in the tool System Architect. The use of this tool was very effective and resulted in a very clear and formal specification.
2. The R&D manager, the hardware engineer, and the software engineer followed a course on FPGAs. They expected to capture all the ins and outs of the technique and tools after this course, which was clearly not the case. It would have been more adequate to attract a subcontractor, who could participate in the design and give a training-on-the-job. In that case, the design time would have been less as well as the design costs.
3. When ALVA started to design the FPGA they encountered some hidden bugs in the synthesis tools. Some were related to wrong usage of the tools. Others were real bugs. In one particular case, it took quite some time before it became obvious that the tool caused the problem. The distributor contributed to the solution and finally a workaround for this problem was given.
4. Because ALVA's initial work plan was revised with the TTN, the work plan was expected to be realistic. The learning curve however took more time and bugs in the tools and some design errors caused an unexpected delay.
5. A barrier that occurred during the application experiment was the yield of the PCB's. ALVA and their manufacturer of the boards were going to use Fine Pitch components for the first time. The manufacturer expected no problems, but it turned out that the first production run of PCB's had a very high number of defective PCB's, and soldering of these fine pitch components appeared to be a problem. The production had to be optimised, which caused some additional delay in the production phase.

13. *Knowledge and experience acquired*

ALVA acquired the following knowledge and experience:

1. Systematic design of complex hardware: ALVA left the trial-and-error method behind and now simulates the designs before putting them into hardware. In the future, they will simulate their designs even more thoroughly. ALVA is highly content about the used specification method and related tools, and will certainly continue to use them and recommend them to other parties.
2. Use Ward-Mellor method: This is seen as one of the major benefits of this project. With this method, also the interface between the hardware and software can be specified very well.
3. Learn to use the CAD tool System Architect: This tool is using the Ward-Mellor method and it is a very useful and consistent tool to use for specifying both hardware and software.
4. The use of an Hardware Description Language. (Verilog): For more complex designs the use of an HDL, in stead of schematics, is inevitable. Some parts can still be done on a high level schematic and then translated into HDL. However, the learning curve was higher then expected.
5. The use of a HDL simulator: Of course, the design is also simulated in a HDL simulator. A simple tool was used, released by Quicklogic in order to implement design in their FPGAs
6. Design and use of FPGAs: ALVA has gained valuable knowledge about the possibilities and limitations of FPGAs.
7. The marketing of the product is not focussed on the FPGAs. However, ALVA found out that the use of such a high tech solution is extra appealing for the end user.
8. The competitive edge of the new product was increased by the application of the FPGAs. In the marketing material, the FPGAs were mentioned.
9. The project planning and project management was a learning case for ALVA. The project risk and the learning curve where difficult to predict. The skills in this area are increased during this project.

14. *Lessons learned*

ALVA learned the following lessons:

1. A training course does not deliver an expert. The ins and outs of the new technique and limitations (bugs) of the tools are not taught. These can only be learned by design practice.
2. Intensive support by an expert is necessary. Using an experienced subcontractor, who could do part of the design and train the engineers on-the-job, would have been a better approach and would have avoided many of the above mentioned problems.
3. Put much effort in the specifications and review it. Only some details were missing in the specification, which were added during the design.
4. Make an FPGA design synchronous. Debugging an asynchronous part was very time consuming.
5. Formalise the submission for production. 50 FPGAs were inadequately programmed by the producer of the PCB's, due to some miscommunication.
6. Fine pitch SMD components can give problems with the production of the PCB. In the first production batch 50% was defective due to soldering problems of the fine pitch FPGA. Designers/producers should be aware of this problem.

The main barrier in the development of the demonstrator was the FPGA technology itself. Especially the use of tools and the lack of knowledge on the restrictions were an unpredicted risk.

15. The future: Industrialisation and internal replication

The Application Experiment resulted in a prototype for a new product in August.

In the original plan, a market introduction was foreseen in December, four months after the realisation of the prototype. In order to make the product ready for production, a housing had to be designed and developed, problems with the rubber keys of the keyboard had to be solved, different modules for the power-supply unit had to be developed for individual countries, EMC approval had to be acquired and special test equipment for production tests had to be developed. Despite the ambitious planning, first products were delivered before the end of the year. Looking back, this appeared to be too soon, since changes on the product had to be made in December and January.

A product team has brought this prototype to production. The same team also was involved in creating the marketing and sales plans.

The total additional costs to get the product to market were approximately 100 k€.

The production department of ALVA produced the new product with the existing means.

The ABT4 is in production and so far, no problems occurred. The production of the PCB is subcontracted to ARVOO, a company that is specialised in PCB production. The one-time programmable Quicklogic FPGAs are programmed and delivered by SEI Benelux.

In future developments of the Braille terminals it is expected that the FPGA, developed in this Application Experiment, will not be used anymore. At the start of this AE, it was expected that FPGAs would play an important role in all future products of ALVA. However, the computer world is moving fast and has delivered a new standard called Universal Serial Bus (USB) for connecting peripherals. There are already standard communication chips available for this digital bus. It is also expected that within a couple of years, most blind and visually impaired users will have a PC with USB at one's disposal.

Therefore, the future Braille terminal will be based on USB. A consequence is that for a communication controller in next Braille terminal an FPGA is not necessary anymore.

However, FPGA technology may still be needed for the Double Touch Cursor.

The specification and design methodologies used in this project will be used in future projects for sure.

16. Improvement in competitive position

The expected sales with and without the Application Experiment are not easy to calculate. The new product was released at a good moment. The sales where already good within a half year.

In the following table, the realised sales figures are given for the new and old product and a conservative prognosis of the near future. It is the objective that the old model will still be supplied as a low cost model.

Type ABT	1995	1996	1997	1998	1999	2000	2001	Total
340	864	770	732	680	554	357	178	4475
380	1091	785	1086	997	468	325	195	5327
Without FUSE	**1955**	**1555**	**1818**	**1677**	**1022**	**682**	**373**	**9082**
440 *		178	503	1299	854	672	358	3864
480 *		228	884	1065	1563	1268	845	5853
With FUSE	**1955**	**1961**	**3205**	**4041**	**3439**	**2622**	**1576**	**18799**
Improved Profit due to FUSE	*0*	*20,3*	*69,35*	*118,2*	*120,85*	*97*	*60,15*	*485,9*

Table E: Sales overview (1000€)

The total cost of the experiment was 60 k€ of which 31 K€ was the FUSE investment. Further costs to get the product to market were approximately 100 k€, which included redesign prior to production.

The investment to develop the new product is much more than one partial component such as the FPGA. A return of that investment for the AE alone (FPGA development) is therefore difficult to give, but if we assume that the increased sales were due to the FUSE experiment and that the profitability improvement due to FUSE is 5% then from the table it can be seen that the AE investment is returned within 2 years with an ROI over the 6 years of sales of 300%. Indeed, the figures shows that the sales of the new terminal (ABT440/480) has relative quick reached the sales figures of the existing terminal (ABT340/380).

The new ABT4 Braille terminal has more functionality than the ABT3: Double Touch cursor and internal speech synthesiser. The end-user price of the ABT4 is about 20% higher than the ABT3. The cost price of both products will hardly show any difference. This means that the margin of the ABT4 has increased by about 40%.

The ABT3 is still sold in markets where a low price is important. The ABT4 is sold in the countries that want high functionality and can afford to pay a higher price. Presently the amount of ABT4's sold equals the number of ABT3 's. The new ABT4 product has improved the profit on ALVA Braille terminals by about 20%.

The quantity of purchased Braille terminals remains the same as previous years. Without renewing the Braille terminals, this number would definitely have dropped by about 20%.

17. Target audience for dissemination

This AE is a good story about common practice at a typical SMI. Something can go wrong during projects, but the end-result still justifies the effort. The best practice experiences they can share with others are related to project planning, new technology know how transfer and the nature of designs in highly integrated circuits. This FU tried to do everything themselves and only used free support from the supplier of the components. The importance of a proper process for tool selection taking into account life cycle costs can be articulated..

The FU has experienced that using new development-tools right from the start of a new product design is not to recommend. It is advised to become familiar and experienced with new tools on a test/demo design, rather than use a new prototype product to learn from mistakes.

The experience in this AE will be of interest to:
- small innovative companies

- producing small series
- who are service oriented
- and have products with a human interface

These companies can be found with PRODCOM codes

2921 Furnaces and Furnace burners
2956 Other Special Purpose Machinery
3002 Computers and Other Information Processing Equipment
3310 Medical & Surgical Equipment and Orthopaedic Appliances
3320 Instruments & Appliances for measuring, checking, testing etc
3330 Industrial Process Control Equipment
3543 Invalid Carriages