FUSE Demonstrator Document
FUSE Application Experiment Number 503

Monitoring TTN: IAM F&E GmbH, Braunschweig, Germany

SMD-PCB for microprocessor controlled bus-valve with sensor electronics

Abstract

Meyer-Lohne designs, manufactures and installs computer-controlled feeding systems for pigs. The main target of the experiment was to develop the capability within the company to design and produce SMT(surface-mounted-technology)-based electronic equipment with new control features to satisfy the markets demand for better feeding systems with better economical and ecological properties. The product to be improved is an electromagnetic air-pressure membrane valve for liquid feeding systems.

The Application Experiment took 13 months (01.07.1996 - 30.07.1997) with immediate development costs of 100 KECU. The payback period will be 1.5 years. The product lifetime is about 6 years. The ROI over the product lifetime is about 400 %.

The target audience could be companies that develop electronic equipment only in conventional through hole technology and companies that produce systems with many far arranged electric controlled actors. The AE proves the advantages of small-size SMT in hard environment.

1. Company name and address

Maschinenfabrik Meyer-Lohne GmbH

Am Hoevel

D-49393 Lohne

Germany

2. Company size

Number of employees is 43, with 3 involved in electronic and software development. The turnover is about 8 MECU.

3. Company business description

Meyer-Lohne designs, manufactures and markets liquid- and dry-feeding systems for pigs. The essential function of these systems is the distribution of feed-portions with the help of spatial far distanced electromagnetic air-pressure valves. In addition to production the company is involved in installation of these feeding systems.

The company's products include tanks with stirrers, pumps, air-pressure equipment, valves, fittings and control-systems. The valves in connection with control are the subject of their application experiment. Figure 1 gives an overview about a simple feeding system. In reality the feeding plants are much more complicated. For example up to 20 stables with in each case 500 pigs, amount up to 1000 feeding valves with distances up to 500 metres.

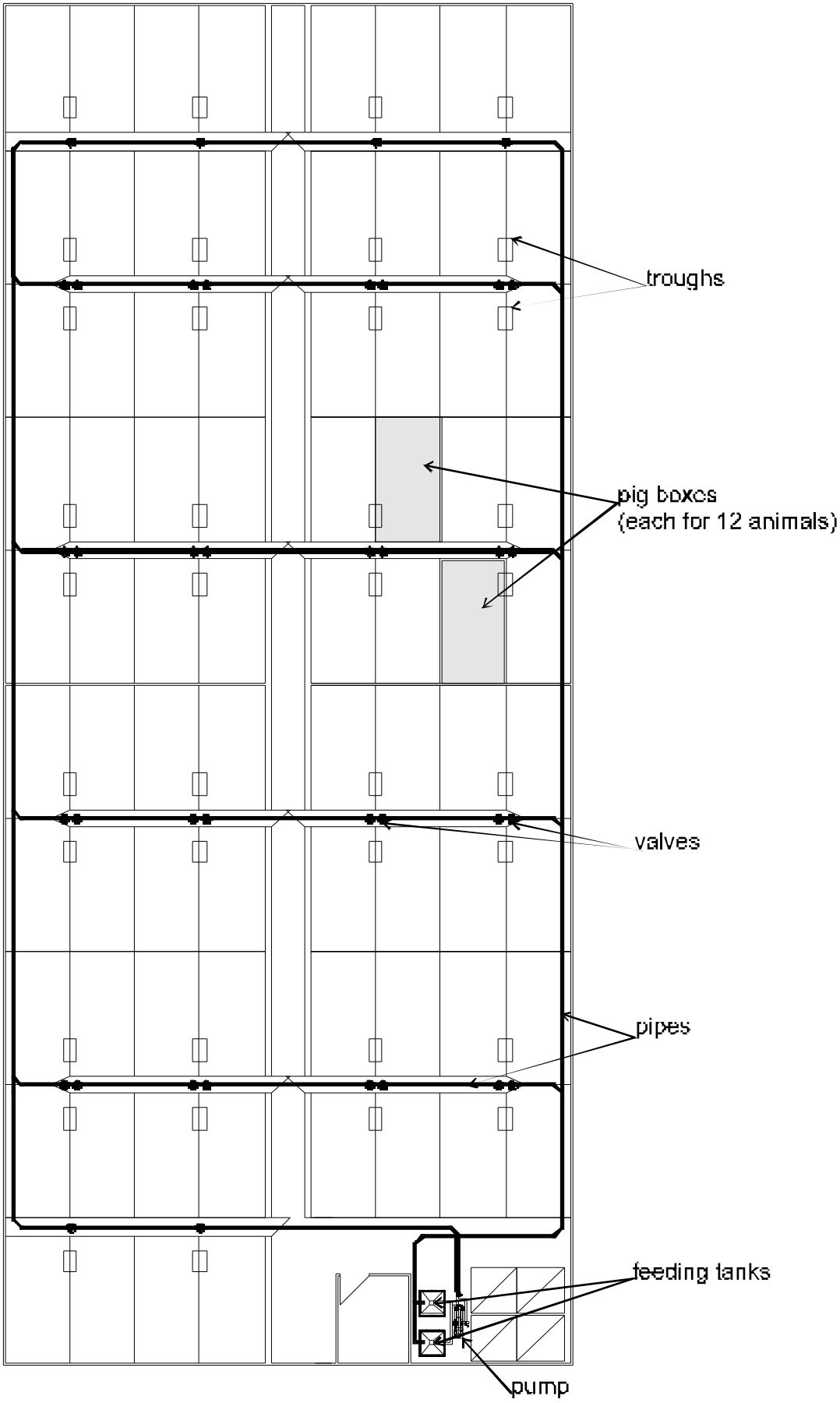


Figure 1: Scheme of a simple farm with only one stable

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

Meyer-Lohne produces liquid and dry pig feeding systems. Their customers are independent farmers, agriculture companies and dealers. The market percentage in Germany is about 20%. They have dealers in the Netherlands, Finland, Great Britain, France and Austria and also sell in East-Europe with different percentages. Computer controlled feeding systems are widely accepted and also offered by a number of competitors, like Big Dutchman International GmbH, which claims to be the market leader in pig-feeding systems, Schauer Maschinenfabrik and Howema Gerätebau, just to name a few. Feeding valves for liquid and dry matter are an essential part of the computer controlled feeding systems. Every installation contains a few dozen up to more than 1000 of these valves. In current systems, wiring of the valves adds significantly to installation costs and reasons for malfunctions, e.g. due to corrosion. Separate sensors supply feed-back to the control unit. The market price per valve is around 100 ECU. For the overall feeding system, a mixing facility, pumps, pipes and control system are required. These central components significantly differ in price according to capacity, performance etc. Meyer-Lohne is among the 10 major producers for pig feeding systems, which all offer similar products.

5. Product to be improved and its industrial sector

The product to be improved is their electromagnetic air-pressure membrane valve for liquid feeding systems. In conventional way the valves are controlled by a relay matrix like shown in Figure 2. To realise this connection 2 cables with 10 wires each are needed. At each valve the isolation of both cables has to be removed and the wires (in example singles:4 and decimals 50) must be identified. After connecting the wires to the valve the cables must be isolated with special expensive rubber material. In stables with bad light and perhaps animals in the boxes this a very difficult and error-prone work.

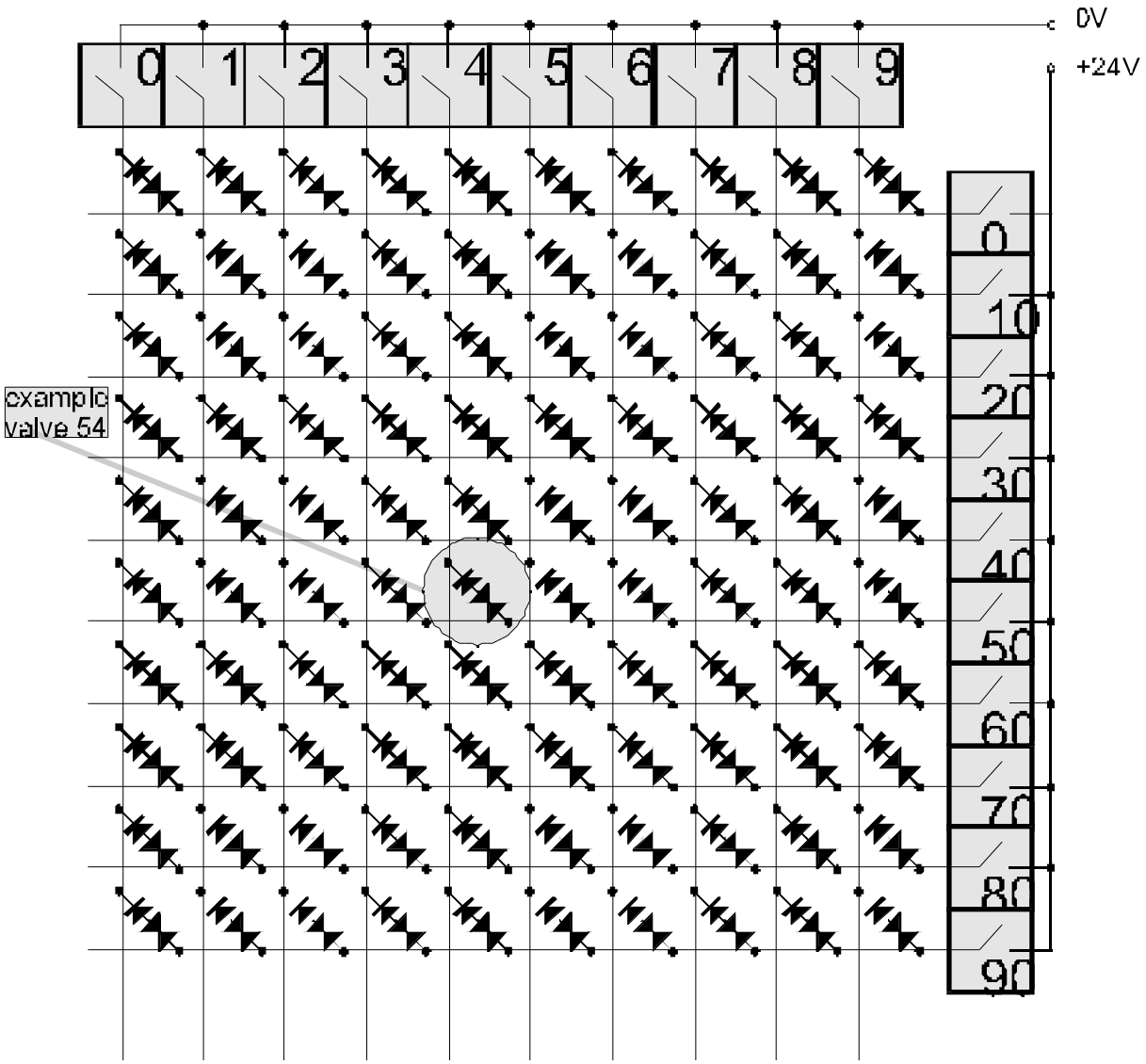


Figure 2 : Relay matrix to control 100 valves

In double valve systems and if sensor feeding is desired, the cabling effort will increase by factor two or three. A special box is needed for every valve and 8 connections have to be done. The following figure gives an impression of the conventional wiring effort.

Figure 3: Wiring effort to connect one double valve with sensor to the matrix cables

6. Description of the technical product improvements

The basic idea was to integrate electronics in the valve, to make a bus connection possible. The primary effects will be easier and faster wiring and better protection against harsh environment. Secondary effects will be elimination of mechanical contacts (relay), self-test possibilities and easier valve-control. Use of microelectronic also offers the possibility for immediate control of two valve per trough and the sensor-capability without additional wiring. Figure 4 shows the bus-concept.

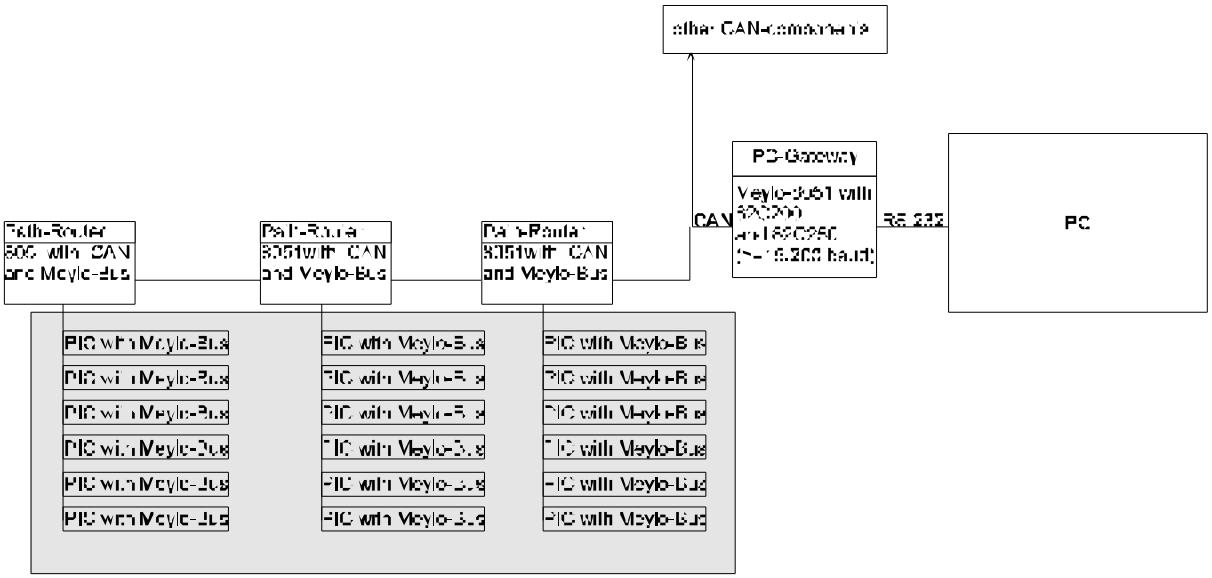


Figure 4 : The Meylo-Bus concept (the grey area shows the subject of the application experiment)

A number of valve controllers (PIC with Meylo-Bus) are connected to a CAN-Path-Router for data exchange over longer distance with the control PC. The PC communicates with the path router over a CAN bus. The PC interfaces to the CAN bus through a PC gateway. The PC is a standard component with software to control ingredients and feeding time and to perform diagnostics.

Figure 5 shows the block diagram of the electronic part of the valve. The component contains the functionality to control the valve and to evaluate the sensor-state. So the feeding computer can detect if a trough is empty or filled. These information is very useful to determine the valves and animals state:

- An empty trough immediately after feeding indicates:
  - The valve may not have opened
  - Another valves or the pipe may be leaking
  - The feeding quantity may be to small for the trough
  - The sensor may be defect
- Sensor-message is „full“ for a longer time than the value of „max. full time“ indicates:
  - The sensor may be defect
  - The pigs may be ill
  - The valve may be leaking
- A “full”-message after an „empty“-message without feeding indicates:
  - The sensor may be defect
  - The valve may be leaking
  - Another (main-) valve may not have opened

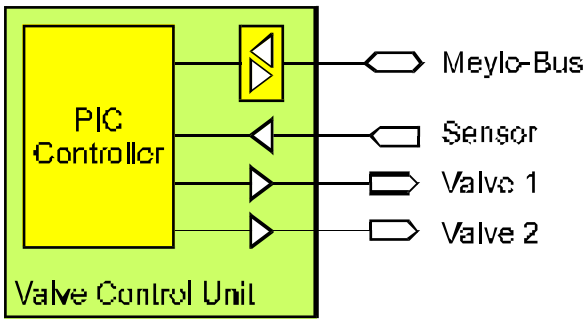


Figure 5: Block diagram of electronic part of valve

The hunger determines the feeding-times and -quantities. To avoid excessive consumption the computer calculates the needs of the pigs and can change the feed-quality by mixing a high and a low quality feed with the help of two valves in one trough. This new technology improved ecological and economical properties.

To connect the valves, a cable with only four wires is needed. Two for power supply and two for signal line. Each valve contacts the wires in the same sequence. The addresses will be patched with help of a service jumper by software. A special housing with pin-adapter makes connecting a valve as easy as screwing two screws.

Figure 6 : Put the 4-wire cable into the 2-screw-socket of the planned housing

Finally, the mechanical dimensions of the electronic where reduced. This offers the possibility to insert the SMD-PCB in the valve housing.

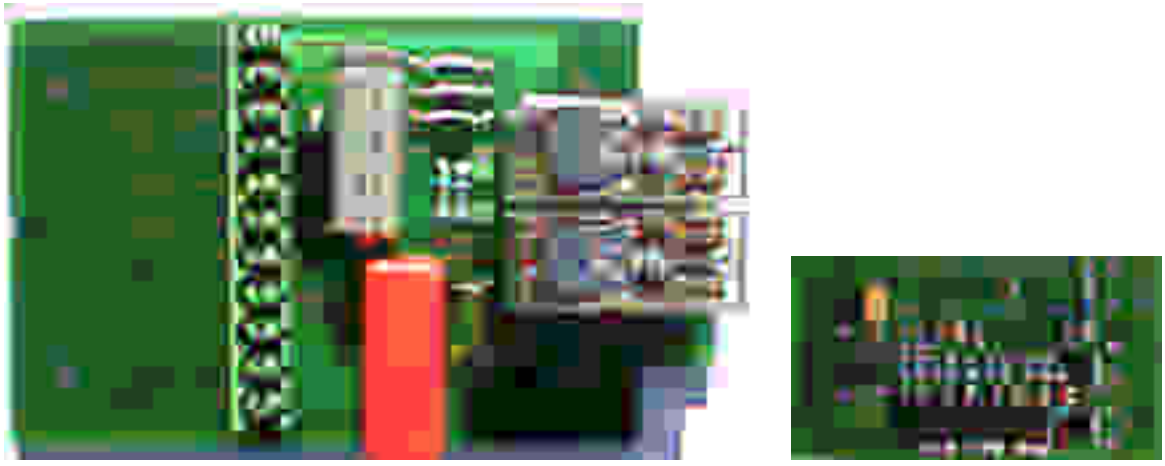


Figure 7 : Compare the conventional and SMD dimensions

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

The choice of the SMT was a crucial prerequisite for integration of the valve control into the valve housing. By saving the separate housing for the control component, housing costs were reduced by 50%. It also helped to integrate the necessary intelligence into the valve, as required for reduction of wiring effort by using a serial bus and for future requirements in feeding systems. The demands were small mechanical dimensions and low production costs. Using discrete components SMT is the best way to build small electronic devices in moderate quantities. SMT-boards can be produced automatically, such that production costs decrease. Already in the first SMT-courses the First User found out that all components they need are available in SMT. Only a suitable power-electronic component had to be found. After checking and testing different possibilities they decided to use SMD-Darlington transistors (MJD 112 from Motorola). Criteria for the choice were:

- Price
- Mechanical dimensions
- Max. current, cooling requirements
- Availability (second source)

The requirements to design SMT-boards are much higher then for through hole PCB's. That's why the First User had to buy a CAD system, suitable for SMT design and get skilled to use it. With the help of their subcontractor they learned the criteria to evaluate the different software-products in the market. Surprising was the great range in price of the programs they looked into. ZIEGLERS „CADDY EDS" was the best fitting CAD-system for them. „CADES-G's" SMT-PCB-performance is still higher, but price and hardware-requirements are too high. And a lot of it's features will only take effect in applications, larger than they plan for future.

The next question was to find out the right bus-technology for the Meylo-Bus. The First User researched 3 possibilities:

LON

Echolon offers high-end network-components. The nodes will be connected with FTT-10 (free topology transceivers) devices. Normal communication network-variables can be used. But network-variables must be bound with a special program and this is a lot of work for many valves. That's why subnet node addressing had been the right way for communication. For addressing, the Echolon-microprocessors provide a service pin.

From the technical view LON had been the best choice but processor and FTT-10 price are to high (25,- DM for only this two components)

CAN

CAN is an industrial bus standard. A lot of semiconductor manufacturers offer microprocessors with CAN-kernel. The nodes will be connected via driver circuit like 82C250 for example. Also RS485 connection is possible. Communication and addressing works with 11 bit identifiers and data-packages of up to 8 byte. The bus is the industrial bus with highest data security. That why the First User choses this technology to connect the feeding computer with the Meylo-Bus-routers and the other IO-components. Because of the high component price per valve (18,- DM microprocessor, EEPROM, watchdog, driver) and mechanical dimensions they didn't chose CAN for the valves.

The bus solution: Meylo-Bus

Evaluating LON and CAN helped the First User to understand bus-structures and communication methods. Searching the market for a cheaper fitting solution was not successful. So they decide to create an own bus - the Meylo-Bus. The strategy is to connect up to 64 valve-nodes to a CAN-Meylo-router module. As driver they selected an open-

collector base circuit. The protocol was designed for the special task. So it got very small, fast and effective.

Price, Size and EEPROM on chip were the criteria to select a PIC 16C54 microprocessor as central component for the valve controller. With this solution the First User has a components-price for driver and processing from about (6,-DM).

Development of future systems an service and repair have been an important aspect to consider, when introducing SMT. In order to be able to build up test applications, to repair and test prototypes and design further SMT-PCB's in the company after the AE the First User bought a SMT-handling station and installed it in their workshop. Already in the test-phase this equipment was very helpful.

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

Meyer-Lohne designs, manufactures and installs computer-controlled feeding systems for pigs. The company has good background of pig-feeding strategies and the depending data and control requirements.

They are producing 8-bit-microcontroler based feeding-computers and high resolution digital weighting systems with serial output. There are only some manually and self test routines to test their conventional products. Valve control takes place with a central decade relay matrix. The system design is done manually. There was no experiences in integrated CAD-software (design - connection list - interactive routing - design rule check - forward and back annotation - production data etc.). Their output to the PCB-manufacturer was a film layout. The PCB's (one or double sided through hole printed circuit boards) were assembled and tested manually in their company.

9. Workplan and rationale

The First User chose two engineers from their development team to perform the AE. They had to :

- Manage the experiment
- Get training
- Select technologies
- Specify and develop the new product
- Replicate the new knowledge in the firm
- Train personal in new technology
- Test the prototypes

Month	1	2	3	4	5	6	7	8	9	10	11	12	13
Management	X	X	X	X	X	X	X	X	X	X	X	X	X
Training	X	X	X	X	X	X	X	X	X	X			
Specification	X	X	X										
Design			X	X	X	X	X	X	X				
Evaluation							X	X	X	X	X	X	X

Figure 8: Workplan

Effort resp. Costs per task	Meyer-Lohne (person days)	Subcontractor (kECU)
Management	20	

Training	20	5
Specification	20	2.5
Design	90	6
Evaluation	40	10
Overall effort	190	23.5

Figure 9: Distribution of Effort and costs

Management

This task includes technical and economical project management and documentation of intermediate and final results for quality assurance and further reference.

Training

During training, general and project-specific know-how on the following subjects was acquired.

- Technical project management
- Selection of design flow and design system
- Selection of components
- Design of SMT-devices
- Handling, fabrication and repair of SMT-devices

Training consisted of a general part, on basic aspects of SMT and a project-specific part, adapted to the concrete project.

Specification

Specification involves definition of objectives and required application system properties, as well as selection of appropriate technologies and design approaches. It involved specification of:

- Application properties and performance
- Electrical and mechanical properties
- Design and manufacturing flow
- Quality assurance measures including certification

Design

The design was mainly done by Meyer-Lohne, just minor support for critical parts was given by the subcontractor. This work-package includes the following tasks:

- Design of electronic circuit
- Layout of SMT PCB
- Verification of specified properties

Evaluation

Evaluation includes prototype production and different tests to assess the new technology with respect to feeding systems. The following test phases took place:

- Laboratory tests of individual components
- Tests within example system
- Field tests with a complete installation in a used stable

The overall schedule was delayed almost 2 months with respect to planning, due to EMC-

problems. The problems became evident during field tests and required additional shielding and thus changes in component housing. EMI was no problem with the conventional approach and laboratory tests, which only considered devices, like pumps, that are directly linked to the feeding system.

10. Subcontractor information

A suitable subcontractor should have experience in

- CAD/CAM and SMD technologies
- Training in most domains of the AE
- Microcontroller systems and power electronics

The subcontractor for SMT aspects has complete SMD-PCB-production and test equipment and offered an effective price for prototype production. So the First User had one partner for all aspects of SMT. Besides the subcontractor has also experience in CAN- and user-bus-technologies. For support in bus-technology they selected a company, which is one of the German leaders in LON-technology. There are also experiences in other bus-technologies and microcontroller applications. From consulting this subcontractor they got decisive suggestions for their own bus hardware and protocol.

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

Knowledge barriers

The high wiring effort to connect the large number of valves was known and Meyer-Lohne had the idea to eliminate this problem by the use of bus-technology. But they didn't know what bus is suitable under financial and technical aspects.

Nobody in the company had experiences in SMD-technology neither in design and components nor in production or service. But for implementing the electronic in the valve SMT was the premise.

Before the AE they always switched the valves by relay. For the new concept it was necessary to eliminate the relay by using power electronic.

Psychological barriers

- Is it possible to handle SMD-components?
- Will bus-data-transfer be sure and fast enough?
- Has power electronic enough immunity?
- Will manufacturers understand the output data?
- Is software addressing to complicated for their dealers?
- What's to do in case of defect valves?
- Can the new product get the CE-certificate?

Technology barriers

- No CAD-system for SMT
- No tools and expertise for handling, repair and test SMD
- Limited technical management capabilities
- Primitive project management skills

Financial barriers

The financial barrier was important for the company, because the profits in agriculture equipment are small and competition is hard. To introduce the new product in their systems, more than one technology and knowledge barrier had to be taken. Especially the EMC-problem increased the risk.

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

The process of overcoming the barriers in adopting the new technology, faced by Meyer-

Lohne, started with the initial contact with the TTN. During this process the company was provided with training by the TTN on the following topics:

- The available technologies and their merits
- The economic and business implication of adopting the new technology
- Technology and subcontractor selection process

The First User conducted, with the support of the TTN, a detailed feasibility study into the improvement of their feeding valve and also other products in the future. This study has resulted in the selecting SMT as the base for their new valve electronic and covered the technical and economic aspects of adopting the technology.

The initial training and the feasibility study have allowed the First User to address and overcome some of the barriers listed in section 11, especially the knowledge barriers, and some of the psychological barriers.

The deciding point to overcome knowledge and technology barriers was the contact to the subcontractors. With common training and training on the project all knowledge barriers were overcome. This, in connection with personal training and the prototypes, was the base to overcome most of the psychological barriers. Unfortunately not all EMC-problems are solved. The dimensions of this barrier were not seen before the experiment. In this point the First User has to do some work, especially in housing, to get the CE-certificate. But they got the knowledge to verify test-results and find a solution.

13. Knowledge and experience acquired

- Managing a scheduled development project
- Assess CAD-systems and their features
- SMT: Components, requirements, design, handling, manufacturing, repair, testing
- Specifying a new product on system and subsystem level
- Get skilled to use First User´s CAD-system (CADDY EDS) on professional stage
- Common knowledge about bus-technologies
- Experience with CAN
- Company-own bus to control decentralises valves
- Power electronics (switches) up to 5 Amps
- EMC-aspects
- Create applications with PIC-microcontrollers

14. Lessons learned

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

Barriers

At the end of this application experiment, the company's experience indicated that there were no significant real barriers to introduce SMT- and bus-technology in their company. 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 in connection with the financial risk were the main reasons that have prevented the company from attempting to introduce the technology at an earlier stage. The company believes that out of all the barriers listed in section 10 the knowledge, psychology and financial 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 SMT and it is sure that further projects will be realised with this technology.

Technology

One of the key reasons for the success of the application experiment was the selection of the right CAD-system and the decision to an own bus. The First User is skilled now to use this

tool professionally and can decrease development cycles. In connection with the SMT-handling station and the continued education of their production workers, SMT will be the most applied PCB-technology in their further products. The good experience with power electronic will result in a step by step elimination of relays from their products. Their engineers got skilled in better, effective and scheduled, project managing.

15. Resulting product, its industrialisation and internal replication

Meyer-Lohne is aiming to introduce the improved sensor-feeding-bus-valve into the market as soon as EMC and housing problems are solved. An additional basis is a new feeding control computer software to support sensor technology. This work was done outside the experiment and one test-farm already works with the new system. Since living animals are involved, the field test has to be done with great care, but the First User is very confident in their new product.

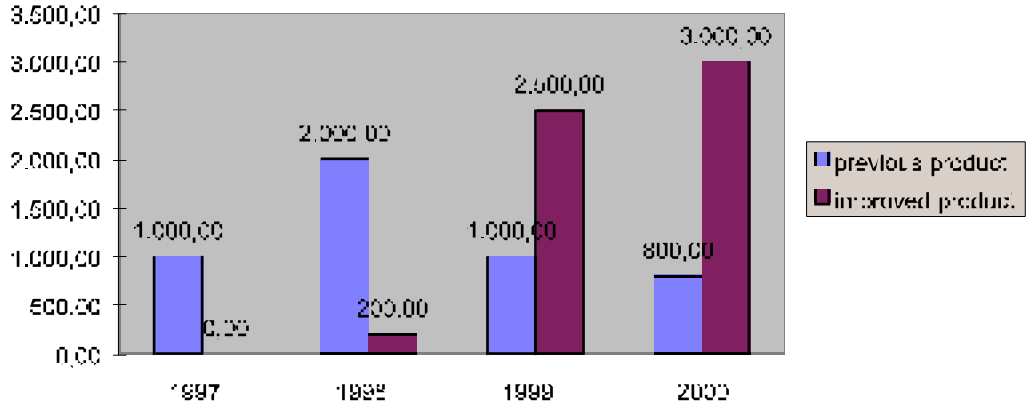
To bring the valves into the market as fast as possible, the feeding systems they sell until availability of the new product, have an option to be changed to the new technology. The First User expect a remaining time to market is about 1 year, with costs for the product industrialisation is about 50 KECU. Meyer-Lohne still has to do some technical improvements, to increase EMC, but already started marketing. Series production will be done by a subcontractor. Repair and addressing will happen in their own company.

Further products will also be done in SMT. In the moment the CAD-software is on a good stage. Meyer-Lohne obtains software updates automatically because of an update contract. The Meylo-Bus will get a solid part of Meyer-Lohne feeding systems.

16. Economic impact and improvement in competitive position

An important innovative aspects of their valve is the immediate connection of valve and trough sensor. The percentage of the „Sensor-Feed-Technology“ is growing and the First User wants to become the German market leader. To achieve this target it was necessary to develop a new generation of „intelligent“ feeding valves. Meyer-Lohne is the first company that connects the valves via a bus system. This will give a considerable advantage over their competitors.

The pig-feeding-system market changes from restricted feeding (3 times per day without feedback from a sensor) to sensor-controlled feeding. So the decline of sensor-less valves will be determined by market. To satisfy the need of sensor-valves already before the AE the First User added sensor ability the conventional valve. Although this was a provisional solution and the mounting effort was high, sales increased in the last two year. Figure 8



shows the comparison of the previous sales and sales prognoses. Sales figures of the previous solution will not decline to zero, because the First User will still sell the older feeding computers, which do not support the Meylo-Bus to small farms, and expect sales to enlarge existing systems.

Figure 8: Compare sales prognosis of the previous and the improved product

Based on the sales prognoses, a price of 100 ECU and a sales profit of 30% the return on investment should be calculated as follows:

Year	Expected sales profit
1997	0 kECU
1998	6 kECU
1999	75 kECU
2000	90 kECU
Summary	**171 kECU**

Expected sales profits

	Costs
Investment AE	100 kECU
Investment others	30 kECU
Summary	**130 kECU**

Investments for development and production preparation

The payback period will be 1.5 years. The product lifetime is about 6 years. The ROI over the product lifetime is about 400 %.

With the knowledge to use the new CAD-system to design SMT-PCB's, the development cycles of further products can be reduced. In compare to their old method the First User will save 50% and more in design effort and costs. Especially design errors may be detected much earlier.

17. Target audience for dissemination throughout Europe

There are two target audience groups:

Companies that are interested in technological aspects of the AE. Companies that currently develop electronic equipment only in conventional through hole technology, or that produces systems with many distantly controlled (electronic) actors. For these firms this experience with SMT-CAD should be very interesting, because development cycles may be shortened and production may be automated. SMT also offers an opportunity to develop smaller electronic products, such that they can integrated directly into the products. The bus-concept and the opportunities of power electronic also are interesting, as is the experiences with EMC-problems

Companies that are working in the application area of agriculture machinery, like harvest machines and stable equipment, e.g. for climate control. Further, companies, that develop and install systems for distribution of liquid and dry matter within a building or production unit.