FUSE Demonstrator Document

Application Experiment – 357

Title

The Enhancement of the Goodyer Skin Rheometer by means of a Microcontroller Based PCB.

Business Description

The design and manufacture of specialist instrumentation for Measurement, Automation and Control. Contract design services in the fields of Real-Time Software and Precision Mechanics.

Electronic Technology

New: Digital & Analogue Circuit Design and PCB Layout

Previous: Real-Time Software

Abstract

GSI Ltd designs and manufactures low volume high cost specialist Test and Measurement Equipment, mainly concentrating on systems for use by the cosmetics industry, and for use in prototype vehicles.

The FUSE project involved the design, evaluation and production of a micro-controller based data acquisition system to log data from, and to control, a Skin Rheometer used by the cosmetics industry to determine the effectiveness of skin creams, which work by changing the hydration levels in the skin. Hydration levels can be inferred by measuring the change in skin elasticity. The system measures the elasticity of human skin in-vivo using a micromechanical motor/lead screw arrangement that moves a lateral probe attached to the hand or forearm of a subject, under force feedback closed loop control.

The existing product used a PC, the new design uses four PC104 cards;

- an analogue card with extensive facilities,
- a PC replacement card with 486 and 20Mb memory,
- a VGA interface card, and
- a display card with full colour camcorder type LCD display.

The budget was 57,000 ECUs and duration 12 months. The project started on 1st March 1996 and was completed on 31st March 1997. The payback period was 12 months and the return on investment 3-fold over the life of the product.

Benefits

- A smaller dedicated redesigned product with extensive functions and facilities,
- The employees and associates of GSI gained new skills in electronic circuit design,
- The project identified a new product, a new market and an agreed licensed route to production and commercial exploitation.

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1 Company Information

1.1 Name

Goodyer Scientific Instruments Ltd

1.2 Address

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Leicester LE12 5LE
United Kingdom
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E-mail eg@dmu.ac.uk

1.3 Company Size

Number of direct employees is 2
Number of regular associates is 4

1.4 Industry Sector

Medical and Surgical Equipment & Orthopaedic Appliances IN3

1.5 Experience and Expertise

Trading for 5 years , designing test and measurement instrumentation for laboratory and industrial use. The skill base is restricted to Real-Time Software and Precision Mechanical Design with a knowledge of sensors, actuators and other relevant components used in the design of real-time systems.

1.6 Markets

The company's capital base was built up, and is now maintained through contract design services. However the primary objective of the company is to design and market it's own range of products. Up until now these have been the low volume, high cost, Test and Measurement equipments already referred to. A common theme of all these products is that all the electronic components are bought in, as our in-house skills are restricted to software and mechanical design.

We had originally envisaged that the new electronic/PCB design skills would only be of benefit to this 'high price - low volume' end of our market. This has given us a number of technical advantages which can be summarized as:

1) Total in-house control of designs,
2) More flexible design capability, and
3) Lower manufacturing cost.

We are expecting orders to the value of 90KECU in the next 3 months for the design of test equipment that will for the first time use our own electronic sub-assemblies.

As a result of the increased confidence that we now have in our own capabilities, we have also sought out, and found new markets for our skills. The best example of this is the fact is that we are now manufacturing a small range of new electronic products for use in luxury cars.

We have, therefore, made the move from offering contract design services to other volume manufacturers, to becoming a fledgling volume manufacturer ourselves.

This repositioning of our market can be simply expressed by the following table of anticipated sales figures which refer only to contracts that use our new in-house electronic/PCB design skills.

Year 1 is 96/97, and refers to orders that we have already received; year 2 is 97/98 and refers to orders that we expect to receive, and quotations already issued that we have a high probability of being accepted; year 3 is 98/99 and represents realistic predictions of sales that will directly result from our ability to design and manufacture new electronic products; it should be considered as a minimum expectation.

Year 1	39KECU	Actual Sales
Year 2	140KECU	Actual and Expected Orders
Year 3	240KECU	Realistic predictions based on current sales promotion effort

1.7 Projected Improvements in Competitive Position

The adoption of new technology has enhanced our competitive position in two markets:

The supply of specialist high value test and measurement equipment

Manufacture of low cost, medium volume, electronic automotive components

The above figures include both areas of sales.

The automotive market is the most exciting outcome. Prior to adopting the new technology our market share was zero. Most of the income shown above for year 1 is represented by actual sales of new automotive electronic components. We are currently bidding for new business in this area that we estimate to be worth 50 kECU over the coming year, and is realistically expected to grow to 187 kECU the following year.

The specialist high value equipment market is also expected grow, but at a far slower rate. Considering only new business that exploits the new skills that we have learnt via FUSE, we have secured the first stage of an order that will be worth a total of 90 kECU, which is included in our year 2 figures. As our sales promotion effort is however involved in promoting our new automotive electronics capability, this is expected to settle down to just over 50 kECU in year three.

The product costs detailed on page 15 indicate the improvement in competitive position both with respect to the current product development and its further application in wider markets with specific reference to the new automotive market penetration.

2 The Product

2.1 Product Code

3310

2.2 Existing design

The GSI Skin Rheometer represents the skills base of the company prior to undertaking the FUSE training and skills enhancements programme. It is used by the cosmetic's industry to measure the elasticity of skin in-vivo, and thus provides a definitive measure of the effect that various skin cream formulations have on the 'suppleness' of skin. The equipment uses micro-mechanical components controlled by a standard PC. Force feedback is used to control the moving arm such that a sinusoidal varying force of +- 3 grammes is applied to the skin, with the resultant displacement being measured with an LVDT (Linear Voltage Displacement Transformer). Analysis of the resultant data yields a number of useful parameters such as elasticity and dynamic spring rate. This technique can also be applied to other materials.

The mechanical unit also houses some bought in electronic signal conditioning units for the LVDT and the load cell. The electrical interface to the GSI manufactured mechanical unit is via a 25 way D type connector with the following 5 signals -

OV, +5V supply
Load Cell output nominally set to 1V per gram
LVDT output nominally set to 0.5V per mm
DC motor drive signal +- 10V

These are connected to a National Instruments AT-MIO-16 analogue I/O card, which is plugged into a host PC. The software reprograms the PC clock to provide a 1khz timing signal, which is used as the time base for a Proportional/Integral (PI) algorithm. This PI loop cycles the mechanical probe through a sinusoidal force cycle, whilst logging the instantaneous position. A regression algorithm is then used to fit a curve to the measured force and load cycle waveforms in turn, from which the elastic and viscous properties of the skin can be derived. The results are displayed graphically on the screen, and stored in a file.

The following schematic shows the configuration of the electromechanical system –

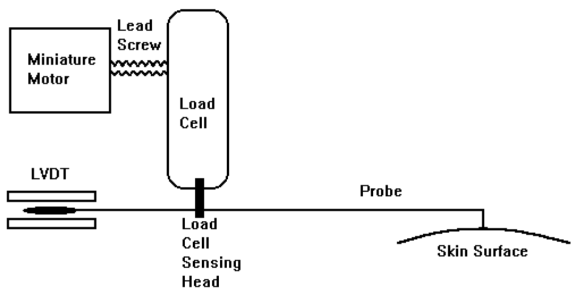


FIGURE 1 Schematic of Electronmechanical Arrangement

The load cell construction is a miniature strain gauge, bonded onto the sensing head. The strain gauge material changes it's resistance when under stress. This electrical phenomena is used to measure the resultant strain.

The LVDT is an electromechanical device, consisting of a pair of coils wrapped around a free moving ferrite core. As the core moves linearly there is a change in the mutual inductance between the coils, thus giving an electrical signal that relates to the linear displacement of the ferrite core.

A single cable from the electromechanical assembly is then plugged into the National Instruments Card. No external power supply is required as the PC's 5V supply is available on the edge connector of the card. Figure 2 shows the overall instrument schematic.

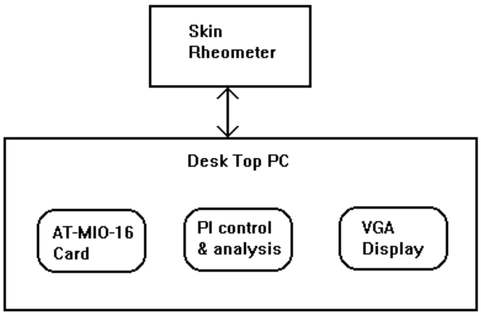


FIGURE 2
Current Instrument Schematic

2.2.1 Control Strategy

The instrument is required to apply a cyclical force to the material under stress. This is achieved using force feedback control. The PC timer is programmed to provide a 1khz interrupt. On each interrupt the currrent strain is measured using the load cell, and it is compared to the desired load that should be achieved at that moment of time. The difference between the two values, one being the Measured Variable or MV, and the other known as the Set Point or SP, is the instantaneous error or E.

E = SP -MV (1)

In order to correct for the error the motor must be driven either forward or back, in order to move the probe to the correct position. The distance that the motor must be driven is directly proportional to the error. Therefore we can derive a motor current from the error signal.

DAC OUTPUT = P * E (2)

Where P is known as the proportional control term. If we used this method only then the closed loop system would be known as a proprtional or P control loop. However, it was found after much experimentation that the motor stalled whenever the sign of the error signal changed. This was due entirely to the inertia of the motor, if it reverses direction then there is a 'stall current' that must be overcome to get it moving again. Once it has started moving this little bit of extra 'push' must be removed. The solution was found to be the application of an integral term with an integral reset operation. The integral term is derived by integrating the sum of the historic errors.

integral = SUM(En) (3)

We then adjust the DAC output proportionally to this value

DAC OUTPUT = P * E + I * SUM (En) (4)

This form of control is known as PI control, because it contains a proportional and an integral term. The dynamic effect of this control strategy was such that the whenever the probe stalls as a result of the error value changing sign, the integral term quickly comes into play and gets it moving again. This extra 'kick' however can also cause the probe to overshoot the desired setpoint. This is due to a phenomena known as 'integral windup'. Because the integral term is cumulative, its' value can grow to such an extent that it dominates the control system. This is cured by resetting the value back to zero whenever the measured error is zero.

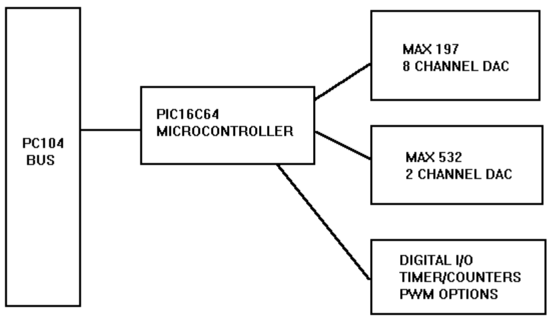
2.3 The Skin Rheometer -- New Design

2.3.1 Analogue Card

The AT-MIO-16 card was replaced with a new card of our own design.
The card is based around a PIC 16C64 processor, and provides the user with the following features -

- 8 Channel 12 bit ADC with either Single or Differential ended input.
- Each Channel independently software selectable to either 0/5V, 0/10V, -5/+5V or -10/+10V
- 2 Matched 12 bit DAC Channels, link selectable to 2.5V, 5.0V, 7.5V or 10V (uni/bipolar)
- Can operate stand alone or as part of a PC104 system
- PWM, Timer/Counter and digital I/O also available.

The analogue card designed for use with the popular PC104 range of miniature PC COMPATIBLE cards, for which a suitable quad-in-line PC104 connector has been fitted. Data transfers between the PIC microcontroller and the maon CPU are achieved by means of an 8-bit bi-directional port. Software drivers are also available for incorporation into user programmes.



A block diagram of the ADC card is shown here.

The minimal requirement for the Application Experiment was a single DAC to drive the motor, and two ADC channels to sample the instantaneous load and position. The ADC design therefore had to contain these features as a minimum, but in order to allow it be used in other products, some additional functionality was included. Maxim devices were chosen for two major reasons, price and technical support. The MAX 197 is a new device that includes the ability to select different input ranges for the analogue signal under software control. This was considered to be of great advantage as it provides the ability for more flexible designs in the future. The card can operate in a stand alone mode, using the local PIC 16C64 microcontroller. Alternatively it can act as a slave to a host PC, the PC104 BUS interface is provided for this purpose. Thus we have called it an Analogue co-processor, as all the work of driving the peripheral devices is handled by the on board microcontroller.

2.3.2 PC Replacement

As the new analogue card has a PC104 bus a standard PC was no longer appropriate, it was replaced with a PC104 system that consisted of a 486 card with a 20Megabyte flash memory configured as a hard disk, a VGA driver and the new analogue card.
The complete PC electronics was therefore shrunk into a box measuring 170mm x 110mm x 100 mm

2.3.3 The Display System

PC104 Cards are approximately 100mm square, but as yet there are no commercially available VGA colour screens which have a similar dimension. The nearest alternative is to use a ‘camcorder’ display, which accepts NTSC or PAL colour signals; both have totally different timing requirements to VGA. Therefore we have developed a modified BIOS for use with any PC that instructs the VGA driver device to generate signals at NTSC or PAL scan rates. This allows us to develop graphics software on a standard PC, which is subsequently displayed on a ‘camcorder’ display.

As it is anticipated that PC104 systems would be embedded into an instrument, we have also developed a GRAPHICS DISPLAY INTERPRETER (GDI). This GDI uses an ASCII script to define up to 8 different screens, with primitive display ICONS (such as bar graphs) attached to active variables on the system. Such an approach gives a designer the ability to create new animated graphics screens in a matter of hours, by simply editing the ASCII script file, and downloading to the embedded instrument.

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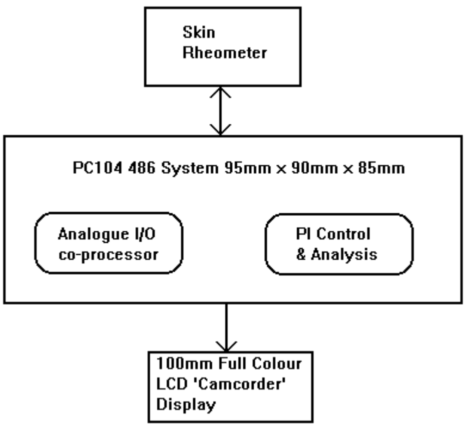
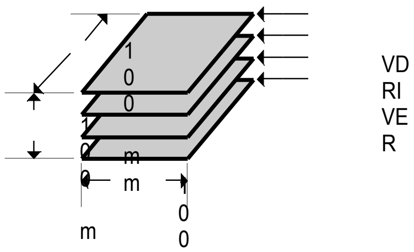


FIGURE 3 New Instrument Schematic showing use of the miniature PC and Display

The mechanical construction of the electronics is shown below and comprises of four PC 104 cards, including the camcorder display, stacked as a cube. The power supply is separate and can be on a PC104 card if required.



Construction of Electronics

Camcorder

PC 104 VGA

Goodyer ADC Card

PC 104 Embedded Card

3 Choices

3.1 Design methodology

The major objectives of the AE was to redesign the Skin Rheometer system to :

- Produce a more cost effective product to enhance sales,
- Significantly reduce the equipment footprint on the testing benches,
- To acquire the following new technology skills:

  Enable the specification of electronic system hardware.
  Design of embedded PC controller systems.
  Design of analogue and digital systems for use in conjunction with embedded PCs.
  The implementation of the these designs on printed circuit boards.
  Manufacture and assembly of these printed circuit boards.
  Integration of commercial equipment with specifically designed equipment.
  Testing sub system components and the total system including the system software.

GSI Ltd has developed a Skin Rheometer that was based upon a standard IBM PC, standard analogue input/output cards, a dedicated mechanical system and system software. A significant investment was in the system software.
To protect this investment it was decided to use embedded PC controllers. These controllers can run software developed for the IBM PC version of the system with minimal modification. The companyd surveyed the market for embedded PC controllers and decided to adopt the industry standard PC104 format. The PC104 format has a footprint of 100 mm. by 100 mm. which is considerably smaller than a standard IBM PC. They employ a quad-in-line interconnect system that allows the user to construct a compact 'stack' of cards to meet any specific requirement.

GSI Ltd purchased an embedded PC controller and VGA graphics display card from DSP Design LTD who are one of the few European based manufacturers of PC104 cards. The additional requirement was to designand manufacture an analogue interface card that was suitable for use with the Skin Rheometer, and to procure a display with a similar footprint to the PC104 cards.

GSI Ltd had been experimenting with the use of camcorder LCD colour displays, which do have a similar footprint to that of the PC104 card. The VGA system, however, has different line and raster scan rates for the display than is required for the camcorder display. The BIOS strusture of the embedded PC can be modified to accommodate the new format and E. Goodyer can supply a paper on this technique, which is freely available.

GSI Ltd also need to design an ADC card. It was decided to make this design compatible with the PC104 format, and to make it able to operate in stand alone mode for use with other new developments. The design would therefore have a microprocessor control element to interface to the PC104 system, control the board in an independent mode and to carry out the ADC process. The power requirements were such that the processor should be of CMOS construction and have a fast program execution. It was decided to use an Arizona Microchip PIC 16C64 to meet these requirements.

The use of 3 identically sized system boards together with the camcorder display would produce a Skin Rheometer system that would form a cube in the order of 100 mm. x 100 mm. x 100 mm. This unit when boxed together with its power supply would have a considerably reduced bench footprint whilst enhancing the system performance and reducing systems costs.

To facilitate the design of the ADC PC104 card, assistance was needed by the company in the use of design tools for electronic systems. The primary design tool to be used was a CAD tool for the schematic circuit capture and the design of printed circuit boards. With the assistance of the sub contractors various CAD systems were evaluated to determine the most appropriate one for the company with regard to price, performance and ease of use. Training was provided by the sub contractors in the use of the CAD system, design techniques and choice of components.

Because of the predicted low volumes of the ADC card and the need to be able to hand assemble it was decided that surface mount techniques would not be used in the design of the printed circuit board. Double sided plated through hole techniques would be used in the design.

3.2 Choice of Design Tools

During the Application Experiment schedule and prior to purchasing the CAD system, a survey was made of competing and available PCB CAD packages:

The initial choice of design tools was to use the OrCad CAD environment because of its ease of use, flexibility, familiarity, comprehensive quality assurance and the past experience of the subcontractor with previous designs.

In the event, and after investigation, the following choices were available:

1. Highly advanced packages such as OrCad and PCAD priced at 4000ECUs
2. Very cheap packages priced at 300ECUs
3. Middle ranged products such as PROTEUS costing around 2000ECUs

The low cost packages were rejected as they offer little in the way of integrated or sophisticated facilities.

The expensive packages were clearly the best technically, but for an SME the costs are prohibitive.

We made the choice to buy Proteus which had a high level of sophistication at a very reasonable price, though it lacks the sophistication of the library creation aspect of OrCad.

It is recommended as being a good value product for SME’s who are prepared to sacrifice some sophistication in order to save on costs.

3.3 Choice of Design Route

The initial choice of route to take in the development cycle for the new product using new techniques was made from the following considerations:

1. Employ a <u>subcontractor</u> to design, produce and test the product and PCB using the estimated workplan schedule of 45 days at 500ECUs/day **22.5K**
2. Employ an <u>additional Engineer/Technician</u> for the duration of the project (1 year) **18K**
3. Bring the <u>technology in-house</u> with the necessary training and using the estimated workplan schedule of 45 days + 13days at FU rate (135ECUs/day) **7.8K**

Our choice was to pursue option 3 because of cost and the new in-house expertise we needed and would get as a result.

3.4 Choice of Fabrication Technology

The number of units to be produced annually did not merit any consideration of ASIC technology for fabrication.

The use of microcontrollers was imperative and printed circuit cards to the PC 104 format were adopted for the reasons explained earlier.

The PCB's containing discrete and standard integrated circuits was designed using PROTEUS CAD.

3.5 Barriers

The choices made during the course of the Application Experiment were influenced by the barriers we initially perceived.

The two barriers confronting and impeding the use of new technology to us, and any SME are:

Technical Risks

The technical risk is that we would choose and attempt to adopt a new technology without adequate training and support. This could result in the launch of a badly engineered product or service or worse still in no product.

Additionally, without support and advice we could adopt an incorrect or inappropriate technology.

FUSE gave us the ability to learn how to apply an appropriate new technology in a virtually risk free manner, with a lot of highly skilled support, both from our TTN and our prime subcontractor.

It is the skilled support and training that overcomes the technical risks, the message being - do not try it on your own without some advice and support.

Commercial Risks

The commercial risk is primarily the damage that could be done to the reputation of the business, as a direct consequence of the technical risks.

Another important commercial risk for an SME is that personnel undergoing a training still have to paid, but are temporarily unable to contribute to the income of the enterprise.

Commercially the company has no choice other than to forgo the income earning potential of staff whilst they are undergoing training, however, FUSE funding does cover the direct costs of the staff during the training programme.

The economic benefits, in new orders and business already obtained, and expected in the future, clearly demonstrates the value of investing in new skills. Indeed if we did not have the support of the FUSE programme GSI Ltd would, in time, have undertaken such a training programme, but it would have taken far longer to complete.

3.6 Steps to Overcome Barriers

The risks outlined above have been very much reduced in successive steps due to:

- Appropriate training and skills acquired,
- Successful product outcome, and
- Confidence gained.

It is recognised that a new and significant technology step will still introduce barriers but each stage of success lowers the perceived barriers.

4 Work Programme

4.1 Workplan

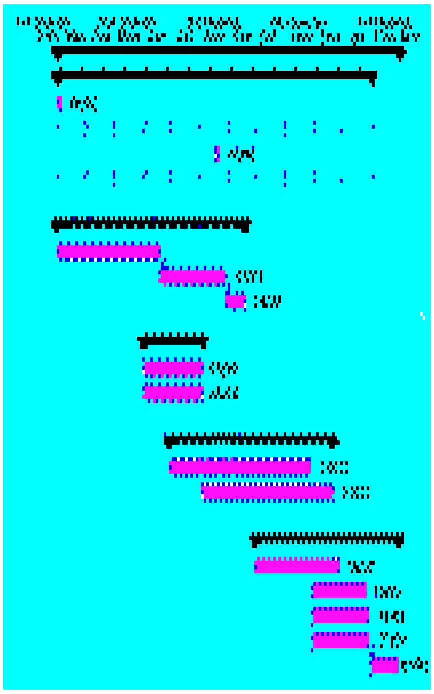
The following workplan indicates the schedule planned in the original Technical Annex and approved by the Commission before the start of the Application experiment. The actual days spent are also detailed.

Application Specific Computers		Planned Man Days		Actual Man Days	
		GOODYER	Subcontr.	GOODYER	Subcontr.
4.1.1 Management					
	Plan, Manage	8	4	11	5
	Report,	9	9	11.5	0
	Dissemination,	7	0	4	0
	Total	**24**	**13**	**26.5**	**5**
4.1.2 Specification					
	Functional	3	0	3	0
	System	5	0	3	2
	Technical	16	6	12	4
	Total	**24**	**6**	**18**	**6**
4.1.3 Training					
	Management	1	1	0	0
	Specific Training	0	0	0	0
	CAD training	6	6	6	6
	Design	6	6	6	6
	Evaluation	0	0	0	0
	Total	**13**	**13**	**12**	**12**
4.1.4 Design					
	System	6	3	10	5
	Subsystem	19	3	10	10
	Total	**25**	**6**	**20**	**15**
4.1.5 Evaluation					
	Prototype Production	2	0	10	0
	Test Rig	3	0	1	0
	Functional Test	5	2	13	4
	Prototype Test	5	0	15	0
	Field Test	5	0	7	0
	Total	**20**	**2**	**46**	**4**
		Planned		**Actual**	
First User Effort		**106**		**122.5**	
Subcontractor Effort (Man days)			**40**		**42**

TOTAL EFFORT	**PLANNED**	**ACTUAL**
Overall Effort	**146 days**	**164.5 days**

The above workplan is shown diagrammatically using Microsoft Project to indicate the project schedule over the 12 months duration. These were prepared before the project was started and used to predict the cash flow in addition to defining the stages of the schedule and the monitoring.

Workplan	Work 112d	1,000's £ 40.5
Management	32d	8.7
Plan	4d	1.1
Management	6d	1.6
Dissemination	4d	1.1
Reporting	18d	4.9
Specification	22d	5.7
Functional Spec.	3d	3.9
System Spec.	3d	0.9
Technical Spec.	16d	0.9
Training	13d	7.6
CAD training	7d	2.8
Design training	6d	4.8
Design	25d	5.4
System design	6d	1.7
Subsystem design	19d	3.7
Evaluation	20d	13.1
Prototype production	2d	11.4
Test set-up	3d	0.3
Functional testing	5d	0.5
Prototype testing	5d	0.6
Field testing	5d	0.3



4.2 *Actual Project Costs*

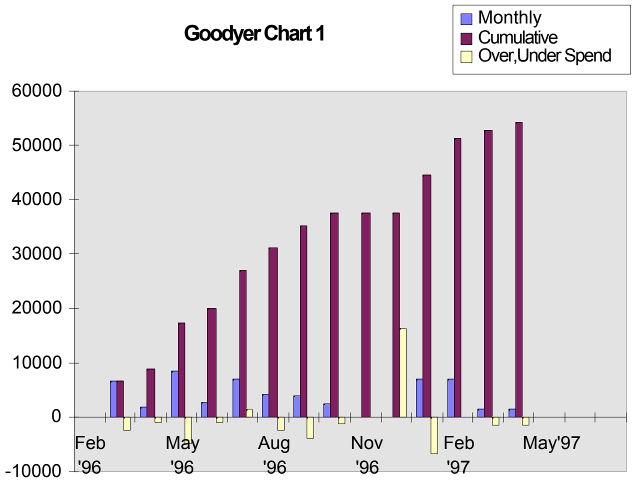
The Application Experiment had an approved budget of 57,000 ECUs which included an initial up-front payment of 14,000 ECUs (25%). The initial payment was paid on 26 April, 1996.

The predicted costs for the duration of the experiment were planned and scheduled as shown in the information given in section 4 under workplan and includes all aspects of the work.

Cost statements were made each month together with the reporting.

The attached charts indicate:

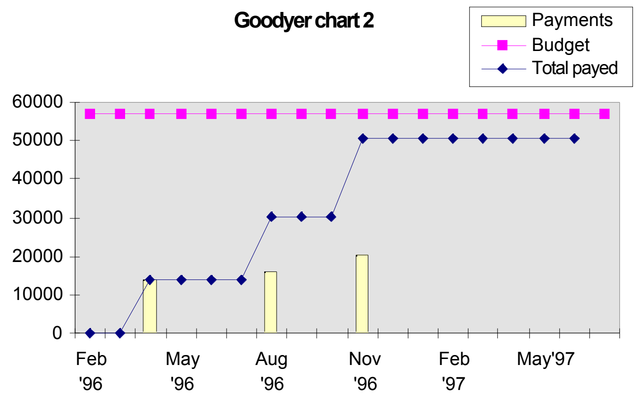
1. The predicted and actual monthly expenditure,
2. The predicted and actual cumulative expenditure,
3. The resulting Underspend/Overspend.



Specifically Chart 1 indicates the excess actual spend over months March to November and confirms the effort expended to catch up with the late start.

Chart 1 shows overall, very small deviation from zero for the over/under spend during most of the experiment.

This shows good management control of cash flow throughout the duration of the experiment and good planning.



The final March/April 1997 entry of 2000ECUs represents a 3% deviation overspend on the budget figure due almost entirely to the constant changes in the £/ECU conversion rate over the duration of the experiment.

The accuracy of prediction and adjustment of working practice especially when associated with an unknown (to us) technology and with such an unpredictable economic environment is commercially acceptable.

Chart 2 indicates the payment dates, cumulative payments and the budget, the costs are in ECUs.

4.3 Product Costs

A number of new products have been produced directly as a result of the FUSE programme, and all will be commercially exploited. Some are already in the market, or under trial.

Below is a summary of the current position:

- The AT-MIO-16 card is currently priced at 1300ECUS, and it can be replaced by our own card which we will market as a stand alone device for around 350ECUs. In it's minimum configuration it will cost 120ECUs to manufacture.
- The Graphics Display System, together with the miniature PC-104 assemblies and data acquisition card, are currently marketed as part of more complex systems for use in luxury cars. These systems provide the driver with a full graphics display capability that is small enough to fit into the drivers display panel. These systems vary in price depending upon complexity, but a rough guide to price is 7000ECUs. So far two systems have been sold.

Of far more importance is that by applying these new skills we have developed new products, and won new markets. For example we are currently manufacturing a range of low/medium cost programmable Electronic Control Units for a number of automotive customers, mainly in the luxury car end of the market. These represent the bulk of new and predicted sales.

We have recently supplied a sample ECU to a major UK based volume car manufacturer for test and evaluation. This has been achieved within 6 months, and is directly attributable to the FUSE project.

4.4 Subcontractor Information

Euro-Projects (LTTC) Ltd,
Pocket Gate, Woodhouse Eaves,
Loughborough, Leicestershire, LE12 8RS

The company is part of the KLB Group and is a privately owned research, development and technology transfer company specialising in new materials, manufacturing processes and product development. The company which was formed in 1992 is currently (1997) managing in excess of 17 million ECUs of research and development contracts across Europe.

The aim is to provide independent and impartial advice and solutions to companies on a cost effective basis by providing access to a highly qualified multi-disciplined techno-commercial team of expertise operating on a low overhead basis. The company also provides access to public (i.e. DTI and EC grant-aided assistance) and private finance and are able to manage projects from the feasibility stage through to the setting up a manufacturing plant.

Subcontractor Role in the Application Experiment

The main support for the Application Experiment came from Euro-Projects Ltd. They provided both management and technical expertise, without which the project would not have run so smoothly. Specifically they assisted us:

- in evaluating a range CAD tools available,
- following selection of the Proteus CAD system they provided training in its use, with particular emphasis on 'Good Design Practice' for PCBs.
- they also provided substantial technical input into the design of the analogue section of the PCB. Particular emphasis was placed on how to mix these technologies on a single PCB; and avoiding the analogue signal degradation that can result from noise coming from nearby high frequency digital components.

Dr Nigel Leighton provided guidance at an early stage in the programme, on the control implications in moving from the AT-MIO-CARD to the proposed new analogue I/O card. His assistance ensured that the target spec for the new card was adequate for the closed loop control needs of the final Application Experiment. This is demonstrated by the complexity of the PI control algorithms that were finally adopted, and have been discussed earlier.

5 Results

5.1 Monitoring

During the course of the Application Experiment extending from May 1996 to June 1997 eight monitoring reports were completed, these indicated an early completion in spite of the slightly late start.

The first monitoring report dated 31.12.96 indicated that workpackages 1/2 were on schedule and the monitoring report dated 31.12.96 showed that all the deliverables were completed excluding the on-going reporting, extended and open ended field tests and the end/presentation.

Specification

The basic specifications of the application experiment are given in section 2 and were completed on time and with the help of the subcontractor. The planning, reporting and specification were complete by August together with a printed article in the European FUSE Newsletter 5 dated October 1996.

Training

Training was completed with the help of Euro-Projects (LTTC) Ltd both in the specification and training phases. The choice of the CAD system to be used was a major task which EPL helped with. They then gave us the necessary training in the use of the PROTEUS CAD system.

The training required the budgeted 13 days including aspects of management and design.

By September/October training was complete and familiarity with the new CAD package and its application to the specific design was well in hand.

As descibed earlier the PROTEUS CAD package was purchased instead of OrCad.

Design

During the design phase of the Application Experiment undertaken during September - December 1996 we acquired the initial skills, with the considerable help of the subcontractor, to:

1. Use PIC design tools,
2. Microcontroller software skills to migrate from 386 - PIC code,
3. PCB layout skills, and
4. Hardware design skills

December 1996 saw the completion of the system and subsystem design.

Evaluation

Prototype construction and testing was completed in January 1997 and to schedule but with the on-going functional and field testing outstanding.

Field testing has been completed, and the completed Application Experiment product demonstrated on the FUSE exhibition stand at the EDTC Conference in Paris, March 1997.

5.2 Lessons Learned

1. The ability to offer a comprehensive design service opens up new markets, and increased sales potential, even for a small company such as GSI Ltd.
2. Formal project planning, management and control has been shown to work, and will be applied in future to other similar contracts.
3. The CAD training, and specifically the schematic capture tools, has enabled us to prepare and exchange, via email, quality outline designs for new systems that can be examined and priced up in detail prior to committing ourselves to formal quotations.
4. PCB/CAD systems can have software bugs which cause frustration and delay.
5. External expertise (e.g. from a TTN) is essential if an SME wishes to expand into a major new technical area.

More than one iteration of the design is nearly always necessary to produce a working model, especially if it involves low level analogue signals and high speed digital signals. This has highlighted the importance of establishing good documentation control procedures

5.3 Knowledge Acquired

1. Expertise - GSI Ltd are now able to complement the existing skills of their staff and associates (i.e. real time software and precision mechanical design) with the ability to design electronic assemblies from discrete components and to layout PCBs.
2. Heightened Confidence - These new technical abilities have created the confidence to seek new markets, where we can offer this all round expertise.

As a direct result of the FUSE programme and subsequent marketing of our new skills we are already securing new sales, and an expansion of our business. Quotations are out for further work that includes the design of PCB's, and we look forward to the steady growth of this side of the business over the coming years.

3. Enhanced Sales - GSI Ltd have identified new markets directly as a result of being able to offer an electronics/PCB design service.

New sales have been achieved in the automotive sector, where we are now supplying small batches of microcontroller based Electronic Control Units.

Quotations have also been issued for the design of new Test and Measurement equipment, that will, for the first time, include our own electronic sub-assemblies.

4. Reduced Costs - GSI Ltd now have an in-house electronic/PCB design capability, that will allow us to reduce the costs of manufacturing new Test & Measurement equipment. This will assist us to win new orders in this market.
5. Project Planning - Formal project planning and management techniques were used throughout this project, with detailed work plans, deliverables, target dates, etc. This procedure was found to be extremely efficient and useful; as demonstrated by the fact the project was completed almost on schedule, and to budget.

6 Dissemination

6.1 Target Audience

The target audience for FUSE information are SME's in the industrial control/automation/data acquisition sector.

Specifically small companies with software design skills and experience who subcontract hardware and PCB design.

Small companies with electronic design expertise and large repeat product orders.

Companies with PCB manufacturing capability and experience who do not have in-house PCB/SMT design expertise, but have the ability to select, combine and utilise standard components in order to produce innovative products.

The results of this Application Experiment are generic and can be applied to a wide variety of products and types of company.

6.2 Replication

Since the completion of this Application Experiment we have undertaken the design of several additional microcontroller cards for use in diverse industries

We have also since undertaken the design of a handful of other microcontroller cards for use in the automotive components industry, which have secured the company new orders in other areas. Examples of these cards are:

- A Motorola 68HC11 unit that dynamically adjusts the frequency of a road speed sensor in order to drive an existing speedometer dial that it is not matched to.
- An Intel 8051 card that interfaces together two vehicle Electonic Control Units (ECU's) that are totally incompatible
- A PIC 16C73 card that operates as a lineariser for a remote sensor, taking all its power from the integral 4-20mA current loop, and providing anoptionl RS485 tranmission signal.

6.3 Publicity

The following publications have resulted during/since the completion of the Application Experiment:

- Article for European FUSE Newsletter No 5.
- Article for the TTN 'In Touch' Bulletin Vol 2 Issue 1, November 1997.
- Demonstration at EDTC Conference, FUSE Exhibition Stand, in Paris, March 1997.
- A Flyer has been produced which highlights the product and the involvement of Goodyer in the FUSE programme.

7 Conclusions

7.1 The FUSE Programme

The FUSE programme ran very smoothly, assistance from the TTN was essential when preparing detailed project planning required by the Technical Annex.

We also found the FUSE approach of identifying a large number of 'deliverables' very useful as these can be used to finely chart and progress the Application Experiment programme.

7.2 Product

The product produced as a result of the AE was a redesigned, smaller, lower cost Skin Rheometer. As a byproduct we have produced a microcontroller card and associated software support libraries.

This has been successfully applied to other new projects as well as the Skin Rheometer.

We have also undertaken the design of several other microcontroller cards for use in the automotive components industry and which have secured the company new orders.

Examples of these cards are:

- A Motorola 68HC11 unit that dynamically adjusts the frequency of a road speed sensor in order to drive an existing speedometer dial that it is not matched to.
- An Intel 8051 card that interfaces together two vehicle Electronic Control Units (ECU's) that are totally incompatible.
- A PIC 16C73 card that operates as a lineariser for a remote sensor, taking all its power from the integral 4-20mA current loop, and providing an optionl RS485 tranmission signal.

7.3 Company Personnel

The technical personnel have all benefited from the training received from FUSE.

Specifically Eric Goodyer and two prime associates were trained in the use of schematic capture and PCB layout tools. We now operate as a team, located in different sites, passing circuit diagrams and layouts to each other via the Internet.

The important benefits that have resulted as a spin off from the training are:

- Firstly, the schematic capture tools allow us to speedily create new outline designs at minimal risk, BEFORE WE HAVE QUOTED FOR A NEW JOB. In this way we can arrive at budgetary estimates for manufacturing costs, and discover technical pitfalls very early on at the quotation stage.
- Secondly, the fact that we now have these skills at our disposal has given us the confidence to seek new business that we would not have attempted in the past; this is exemplified by the new orders that we have already won and referred to above.

7.4 Profits Forecast

We are already achieving new sales as a result of the company's enhanced skills, and a number of quotations are currently either with potential customers, or are in preparation.

There is no doubt that the new skills gained by Goodyer Scientific Ltd are already bringing in financial rewards, and providing work both for ourselves and our suppliers.