FUSE Demonstrator Document
Application Experiment - 2194

Title	All Digital Real-Time Sound and Vibration Meter
Business Description	Castle Group Ltd designs manufactures and markets instruments for environmental pollution monitoring noise and vibration measuring.
Electronic Technology	**New:** Microcontrollers, FPGA and DSP
	Previous: Analogue Design and PCB

Abstract

Castle Group Ltd is a UK company, based at Scarborough, with 13 employees, who design, manufacture and sell instruments for measuring noise and vibration. The company expertise is very strong in analogue circuitry, with an electronics design engineer and one software engineer. The new system design uses DSP and FPGA technologies to produce a small, powerful but energy efficient subsystem with advanced frequency capture features to provide real time signal acquisition and processing. The new product is a Real Time All Digital Sound and Vibration Meter to measure Noise and Vibration using advanced frequency analysis. The instrument is hand held and battery powered.

The instrument will be sold world wide for Industrial Safety noise and vibration legal compliance measurements, for environmental impact assessments and for machinery condition monitoring. Another area of application will be Hand and Arm Risk Measurement (HARM) for the assessment of Vibration White Finger (VWF) and other physical vibration damage in the workplace. VWF is one of the most common physical disabilities currently costing the state vast monies for compensation; it is caused by long term exposure to vibration from tools and machines and renders the fingers painful and insensitive to feel.

Completion has enabled products to be manufactured with advanced frequency analysis features more commonly associated with expensive laboratory class instruments. The project illustrates how a thorough understanding of the principles and capabilities of the new technology is vital for defining the new product specification.

The approved budget was 80K ECU and duration 8 months. The payback period is 1 year and the return on investment sevenfold. The project started 1 September 1996 and finished December 1997.

Benefits

- An advanced, new and flexible component with 5% reduction in manufacturing costs.
- 100% increase in turnover, giving a substantial increase in profits.
- Increased market share, with a breakthrough into the higher spec. upper market products.
- Utilising the new skills and Fuse technology in new (spin-off) products
- Doubled the number of electronic design engineers within the company.

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1. COMPANY INFORMATION

1.1 Name and Address

Castle Group Ltd
Salter Road,
Layton Low Road Industrial Estate
Scarborough, YO11 3UZ
Tel. 01723 584250 Fax. 01723 583728

1.2 Company Size

Castle Group directly employed 13 people throughout the duration of this project of which 2 were involved in electronic system design. There were 4 employees directly involved in the project – 1 electronics engineer, 1 software engineer, 1 senior technical manager and 1 project manager. Castle employees had limited knowledge of microelectronics but considerable expertise in analogue circuit design, software, manufacturing, project management, marketing and selling to world-wide markets.

1.3 Industry Sector

Instruments for Measuring ME, FM, CB, EQ, EQ1

1.4 Company Business Description

The Company has been engaged in the design, manufacture and selling of noise measurement equipment for 25 years and has recently expanded into vibration measurement with particular emphasis on the measurement of Hand and Arm vibration (HARM) parameters. The product range has included both their own designed and manufactured products plus, for the top of the range, imported and represented products. Castle aim to have a wholly own manufactured range, which this project will help, achieve. The expertise in the Company is very strong in analogue circuitry and acoustics theory and application and there is considerable skill in managing sub contractors.

1.5 Company Markets/Competitive Position at the start of the AE

The company delivers to world-wide Health & Safety and Environmental Health markets with particular expertise in the measurement and control of noise and vibration notably in the UK, Sweden, Europe, and South Africa. Pollution monitoring, industrial deafness screening and Automobile pollution monitoring are major areas of involvement.

It is estimated that Castle has 2% of the total world-wide market for sound and vibration measuring instrumentation. The main competition comes from America, Japan and Europe and it is estimated that the market share is 45%, 20% and 35% respectively. Castle has about 20% of the home market.

By incorporating the new technologies the company will be able to produce products which will be better able to compete with products imported from large American and Japanese suppliers. The resulting products will be able to perform to a much higher specifications than would be possible without the use of these technologies and will be easier to manufacture competitively and repeatably. Additionally the design path chosen will enable several products with very different market targets and potential to be made from one basic design and production. The Company is mainly engaged in the lower-to-middle sector of the current potential market and with the new technologies will be able to enter the higher and more lucrative market sector.

The current product designs do not offer frequency analysis beyond sequential scanning of whole octave bands. Noise and vibration are real time events and the new technologies learnt will enable the company to produce instrumentation to provide real time parallel and more narrowly defined frequency analysis. This combined with the multi-channel capabilities will satisfy a much broader and bigger world market than previously possible making direct comparisons of market impact between the previous and new generation of products less meaningful.

1.6 Experience & Expertise

The company has expertise in analogue circuit design, manufacturing, project management, marketing and selling to worldwide markets. The Company has been engaged in the business of noise measurement for 25 years and has recently expanded into vibration measurement with particular emphasis on the measurement of Hand and Arm vibration parameters. The product range has included both own designed and manufactured products plus, for the top of the range, imported and represented products. The Companies aim is to have a wholly own manufactured range which this project will help achieve. The expertise in the Company is very strong in analogue circuitry and in acoustics theory and application and there is considerable skill in managing sub contractors.

2. THE PRODUCT

2.1 Product Code

3320

2.2 Existing Design

The existing product is designed to obtain, process, display and consolidate the results of measurements of sound.

It is a Sound Level Meter based on analogue electronic design components, which feature a high gain, high stability pre-amplifier fed from a precision microphone. The received signal is processed through a true RMS to DC converter.

The signal is then fed to a series of frequency and time weighting circuits before moving to the digital elements of the instrument. The signal processing for integrated values of noise, data logging and subsequent alphanumeric LCD display are carried out under the control of a simple 8 bit microcontroller programmed in assembler language.

Additional analogue circuits provide 10 Octave Frequency Band filters for signal analysis over the frequency range 20 Hz to 20 kHz. These filters are manually accessed in sequence over a two-minute period, which requires a steady burst of noise long enough for it to be scanned for its entire frequency signature. This is far from ideal.

The product is designed and each one is tested and set up to meet the requirements of the International Standards for Sound Level Meters BS EN 60651 Type 1 which are very stringent and require select on test components to tune the unpredictability of the analogue circuitry.

CASTLE GA123 SPECIFICATION
FEATURES

- Automatic Octave 'Snapshot'
- 'A', 'LIN', & 'C' Wtg
- Leq & Lep,d
- Slow, Fast, Impulse & Peak
- Manual & Auto-Ranging
- Auto Calibration
- Elapsed time
- Tactile key pad

MEASURING RANGE

RANGE	PULSE RANGE	INDICATOR RANGE
40	25-103	25-100
60	45-123	45-120
80	65-140	65-140

DETECTOR CHARACTERISTICS
True RMS & simultaneous PEAK (linear)

SIGNAL TO NOISE RATIO
> 5 dB at bottom scale

DISPLAY
LCD 2 x 16 alphanumeric
Temperature compensated brightness control

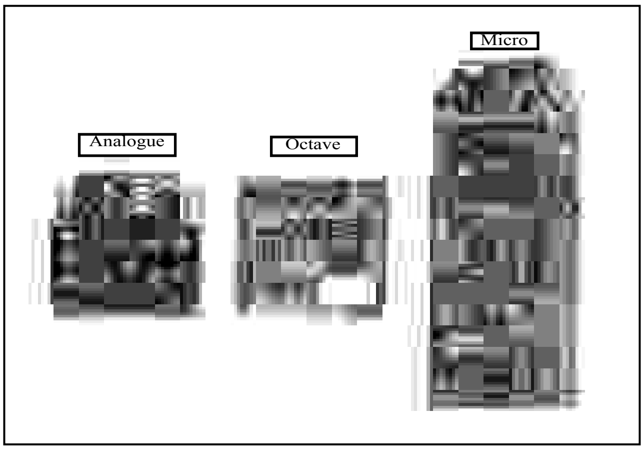
MICROPHONE/PRE AMP

FILTERS
Octave band filters to BS2475/IEC225
Filter centre frequencies 31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1KHz, 2KHz, 4KHz, 8KHZ, 16KHz
Filters can be switched in & out & scanned automatically

FREQUENCY WEIGHTING
GA123 'A', 'C' & 'Lin' to BSEN60651 type 1

Pre-Polarised 1/2" (12.7mm) Type 1
Electret Condenser Microphone
Sensitivity: -27dB +/- 1.5dB re IV/Pa

The current product comprises three printed circuit boards shown below:



Two views of the existing product

2.3 New Design

The new product is a Digital Real Time Sound Level and vibration Meter. The instrument will capture acoustic signals from microphones and accelerometers and analyse the signals over a frequency range of at least 2 Hz to 16 kHz through parallel filters in real time. These filters will be selectable from discrete centre frequencies through 1/3 octave to 1/1 octave bands. The instrument will be hand held and consume low power to facilitate a battery operation long enough for a work shift to be data logged. The target run time is 12 hours but may prove to be nearer to 8 in practice, which is the absolute minimum acceptable. Additional features of the new design over the old are its ability to capture data at a much greater sample rate thus giving higher resolution and accuracy. Also the ability to produce full frequency analysis in real time is of paramount importance for the future markets. A further capability to provide three channels of measurement in real time enables the unit to be offered as a vibration meter.

2.4 Specification

The instrument will provide full digital signal capture and analysis in real-time to meet the demands of BS EN 6051:1994 Type 1, BS EN 60804:1994 Type 1, DS2475: 1964(1988)/IEC225 Standards. The meter will have a range of 0 dB to 150 dB with selectable frequency weighting filters A, C and Linear as defined in the standards. Three time constant filters specified in the sound level meter standards Slow, Fast, and Impulse as well as a true peak response are provided. It will be small, light and consume low power, all of these requirements justified the use of the new technologies. The input to the component will have to be software selectable to accept both a selection of microphones for Sound Level Measurement as well as accelerometers for engineering and human vibration measurement. Auxiliary inputs will be required for temperature, speed in Revolutions per Minute (RPM), and possibly distance measurement. The instrument will provide direct printout facilities via a parallel port as well as inter-connectivity to IBM compatible PC's for downloading of files for further analysis.

The instrument will be offered in the following formats:

- Real Time Sound Level Meter (SLM) for sound level measurement
- Real Time Vibration meter for mechanical and human factor measurements
- A combined Sound and Vibration version

When the combined function instrument is designed and ready for the market further development work may be undertaken by Castle Group Ltd. to design two further instruments of reduced capability using the functionality established in the new instrument. These instruments will be for Sound Level Meter only and Vibration Meter only with fixed functions to provide low cost offerings.

The new instrument will have the following operating modes:

- Sound Level Measurement Meter (SLM).
    - Single microphone input.
    - Double microphone input.
    - Vibration measurement.
- Single channel accelerometer.
    - Single channel voltage of charge amplifier input.
    - Triaxial accelerometer.

The analogue inputs will be processed using discrete analogue circuitry, which will be used to select the required inputs channels and filter characteristics under control of the 16 bit microcontroller.

The analogue inputs to the DSP section will be converted into digital signals by high resolution Analogue to Digital Converters and be presented to the DSP device for the next stage of the signal processing.

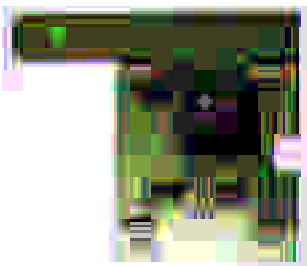
The resultant parameters calculated by the DSP section will be transferred on a periodic basis to the 16 bit microcontroller via a high speed data transfer protocol to be developed by the TDU Technology Development Unit. Subsequent post processing by the 16 bit microcontroller will provide data displays, storage and presentation to various interfaces for immediate printing or off-line storage.

The system will also produce displays of the information processed in a graphical format on an LCD display. In particular display the system with regard to:

- System on or off.
- Amplitude range.
- Sound or Vibration Level Measurement.
- Time constants and Filter selections.
- Charge or voltage amplifiers for vibration inputs.
- Type of display:
    - Static readings.
    - Octave displays and 1/3 octave displays.
    - FFT responses as a spectrum analysis trace.
    - Configuration displays and Engineer set-up screens.
    - Importing firmware programs.
    - Data storage and Data playback.
    - Setting start, end and interval of logging time.

The new component comprises three PCBs shown below:

Microcontroller Board



DSP Board

Analogue Board

2.5 System Architecture and Block Diagram

The Digital Real Time Sound Meter is split into three major functional blocks: ·

- Analogue signal processing,
- Digital Signal Processing (DSP), and
- 16 bit microcontroller processing.

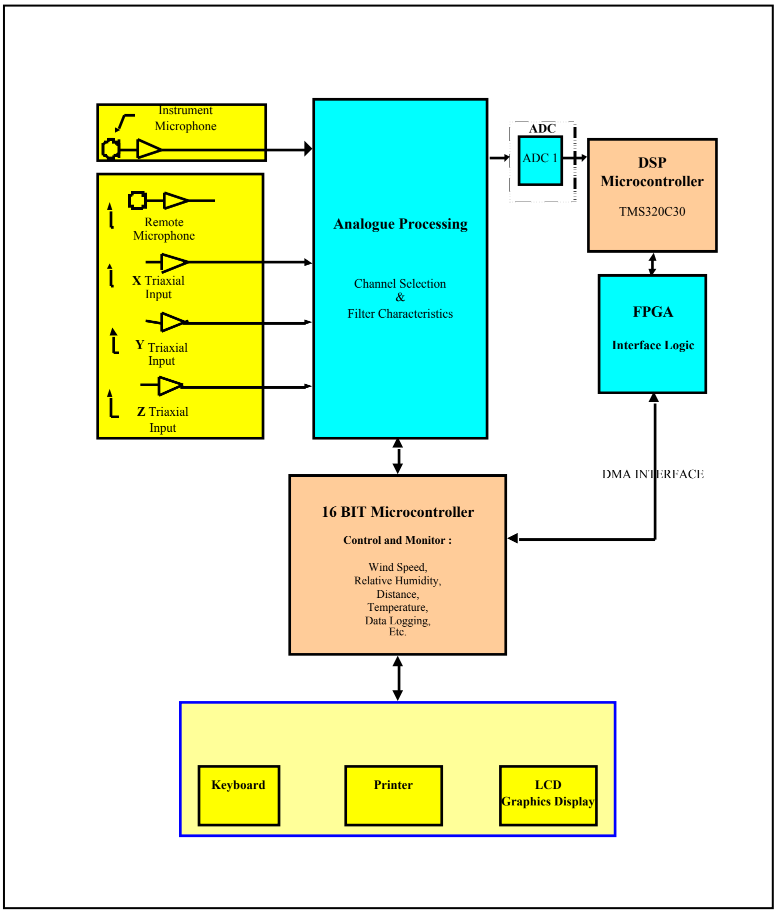
The Analogue Signal Processing Unit provides the matching circuits for the instrument internal and external microphones as well as the triaxial sensor circuits. It is necessary to provide acoustic response for the input signals to match various acoustic bandpass characteristics, e.g. 'C' weighting, A weighting, Linear weighting, etc. It is not possible to implement these bandpass characteristics within the DSP as it is running at 90% of its processing speed to establish all the 1/3 octave filters required in the instrument. The audio signals and bandpass characteristics are established by user interface via the LCD and keyboard selecting the required operational mode. Analogue multiplexers and switches are used under the control of the microcontroller to configure the signals through the appropriate filter and gain blocks prior to signals being presented to dual 16 bit analogue to digital converters (ADCs). The 4 digitised channels are selected and controlled via the DSP device under its programme control.

The DSP device uses time multiplexed software to acquire the 1/3 octaves or octaves as required by the microcontroller selection. The DSP device has no EPROM code space and at power on the code is downloaded from the 16-bit microcontroller programme space via the FPGA. The FPGA provides a bi-directional interface between the DSP and 16-bit microcontroller. The resultant calculations for octave measurements are passed via a dual port RAM in the FPGA to the 16-bit microcontroller.

The FPGA also provides a keyboard reader and the additional glue logic for the system, e.g. address decoder for FLASH and RAM memory.

The 16-bit microcontroller receives the octave information and processes it for storage and display purposes in the required format. The 16-bit microcomputer handles the entire housekeeping tasks and performs all additional input sensing and data outputs.

The system has been configured in these 3 major functional blocks because it would be impossible to achieve the data throughput required using a single DSP or microcontroller and maintain the required power management and PCB size to meet with the hand held operational instrument requirement.



3. CHOICES

3.1 Design methodology

One of the fundamental requirements for the future generation of Noise and Vibration meters is the introduction of real-time signal processing and discrete frequency analysis. The choice of technology to implement this urgent requirement must enable the products to have a long design life with flexibility to enable continual upgrading of the operating software to cope with:

- Changes to International Specification standards.
- Changes to National Test Specification standards
- Upgrading of operating procedures to meet new customer requirements

Castle Group Limited had discussion with design consultants, Technology Development Unit (TDU) and the Bolton TTN to establish the feasibility of the project and determine the microelectronic technologies to be used in the implementation of the project. The Instrument is designed to have a long operational life and it was necessary to choose the technologies to ensure a minimum 8-hour (target 12 hour) battery life. During the lifetime of the product it is expected that International Standards may well be updated and problems may develop in the system firmware, which need modification. There was a requirement for large amounts of stored data for long data logging periods. These requirements mitigated against the design of an ASIC as the charges associated with field upgrades would undermine the cost performance of the system. As there was a significant amount of discrete interface logic and some special interfaces for communication protocols it was decided to include an FPGA to reduce power consumption and the chip count.

The design chosen was a combination of 16-bit microcontrollers, DSP and FPGA technologies.

These components provided the essential functionality, have the required speed and power saving features for the new product while avoiding the high cost and development risk of custom DSP and ASIC chips.

The functional requirements identified the use of:

A Field programmable 16-bit microcontroller which will perform:

- Operational configuration of discrete analogue inputs and filter responses,
- Post processing of noise and vibration data derived in the DSP microcontroller,
- Implement the user interface,
- Interface to ancillary parameter input circuits,
- Display data on an LCD graphics display,
- Carry out the required data logging and
- Produce a hard copy.

A Field Programmable DSP which will:

- Sample single channel, double channel and tri-axial system inputs for the required discrete frequency analysis and FFT determination.

A Field Programmable Gate Array which will enable:

- Logic circuit functions,
- Keyboard interfaces,
- Bi-directional data transfers between DSP and 16 bit microcontroller,
- With reduced power,
- Reduced chip count in smaller space.

3.2 Fabrication Technology

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

With the constraints of size and power consumption the number of chips employed in the design and their size is important for a hand held instrument.

The Instrument was fabricated on a multi-layer double sided surface mount assembly PCB to get a high chip count in a small space to suit the hand held product.

With the assistance of Bolton Institute Technology Development Unit who have appropriate expertise in DSP, FPGA and Microcontroller design we selected the chosen design strategy necessary to achieve the desired route to an advanced and flexible product.

- Develop the product using ‘C’ and an ICE emulator for the 16 bit microcontroller.
- Xilinx field programmable FPGA LCA components.
- To use the Texas TMS320C30 DSP .

Following the development of the Functional Specification the control algorithms for the DSP were investigated to ensure that the required frequency responses and sampling rates could be achieved. This DSP control algorithm was tested using simulation tools such as MATLAB and Simulink. The code was developed for the TMS320C30 DSP device and was run in a development system. The frequency characteristics of the DSP solution was predicted and plotted through the use of the simulation tools and verified using the DSP development system. In circuit emulation tools were used to provide a real time development environment for the DSP and 16 bit microcontroller.

3.3 Barriers

The choices made during the course of the Application Experiment were influenced by the barriers we initially perceived but the expertise and experience of Bolton Institute Technology Development Unit throughout the Application Experiment was indispensable and without which we could not (have easily) succeeded.

The two barriers confronting and impeding the implementing of new technology to us were:

3.3.1 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 the TTN and the 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.

3.3.2 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 while personnel are undergoing training, they still have to paid, but are temporarily unable to contribute directly to the income of the enterprise.

3.3.3 Steps to Overcome Barriers

The barriers outlined above were overcome by:

- The FUSE scheme allowed us to overcome financial pressures, particularly cash flow and the confidence to embark on an imaginative and technically demanding project without some additional financial pressures.
- The TTN helped plan the project, monitor throughout with advice as necessary at critical times of decision.
- Subcontractor advice during the early specification phase.

  This included the correct technology to adopt, and the training necessary for management, tools and design training required to implement the new technology.

  This advice was of considerable help in determining what could be achieved using the new technology thereby enhancing the product.
- The employing of a subcontractor helped overcome what would have become staff availability problems particularly in the design phase if we had made the decision to design in-house.

4. WORK PROGRAMME

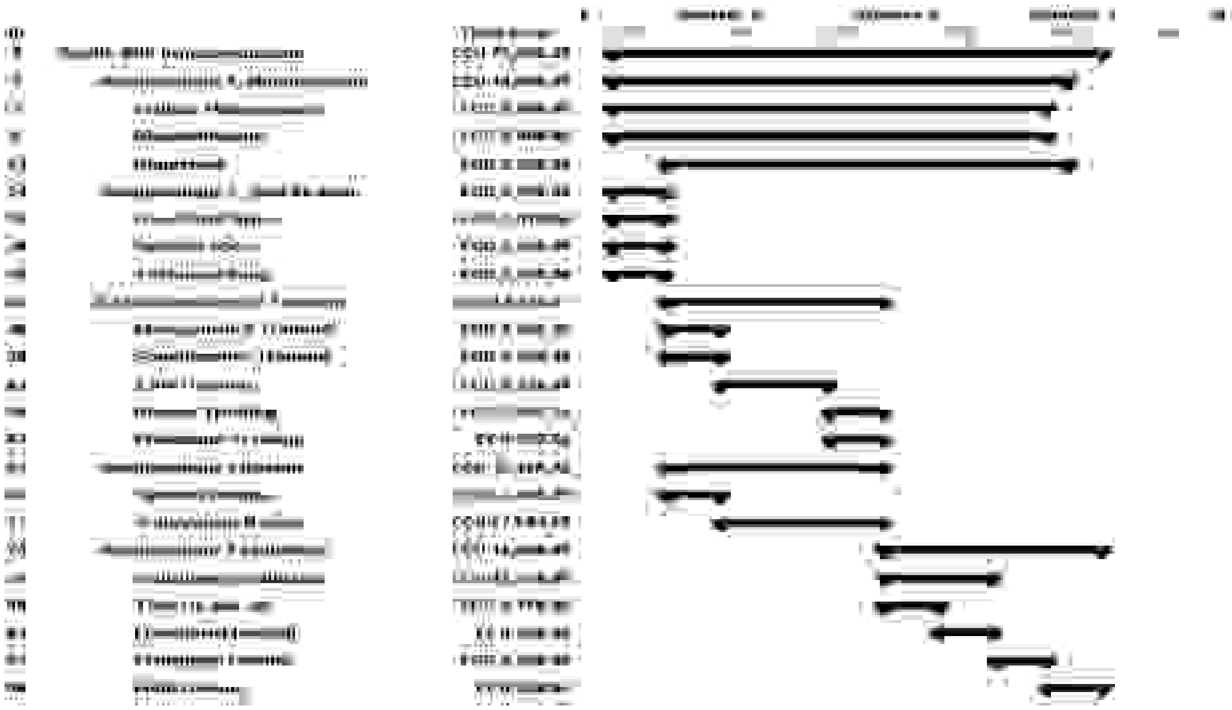
4.1 Workplan

The following workplan indicates the schedule planned in the original Project submission to Brussels. The project was approved by the Commission and was to be completed within 8 months duration as opposed to the planned 12, along with a proportional reduction in funding. In the table below, the planned and actual efforts are compared with the individual efforts attributed to both the First User and main Subcontractors.

		Planned	Actual	
			Castle	Subcontractor
4.1.1 Management	Plan, Manage	10 days	27.5 days	
	Report,	16 days	21 days	
	Dissemination,	18 days	7 days	5 days
	Total	**44 days**	**55.5 days**	**5 days**
4.1.2 Specification	Functional	16 days	16 days	1 day
	System	42 days	47 days	7 days
	Technical	32 days	18 days	3
	Total	**90 days**	**81 days**	**11 days**
4.1.3 Training	Management	10 days	1 day	1 day
	Specification	3 days	14 days	7 days
	CAD	30 days	12 days	6 days
	Design	18 days	4 days	2 days
	Evaluation	2 days	0	0
	Total	**63 days**	**30 days**	**16 days**
4.1.4 Design	System	90 days	62 days	32 days
	Subsystem	211 days	34 days	195 days
	Total	**301 days**	**96 days**	**227 days**
4.1.5 Evaluation	Prototype Production	49 days	18 days	30 days
	Test Rig	10 days	8 days	
	Functional Test	10 days	9 days	
	Prototype Test	10 days	15 days	
	Field Test	10 days	8 days	
	Total	**89 days**	**58 days**	**30 days**

TOTAL EFFORT	Planned	Actual
Overall Effort	**587 days**	**609.5 days**
First User Effort		**320.5 days**
Subcontractor Effort		**289 days**

The above workplan is shown diagrammatically using Microsoft Project to indicate the project schedule over the 8 months duration. The project was planned using an 8 month duration within the 80 kECU allocated by the EC. 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.



4.2 Project Costs

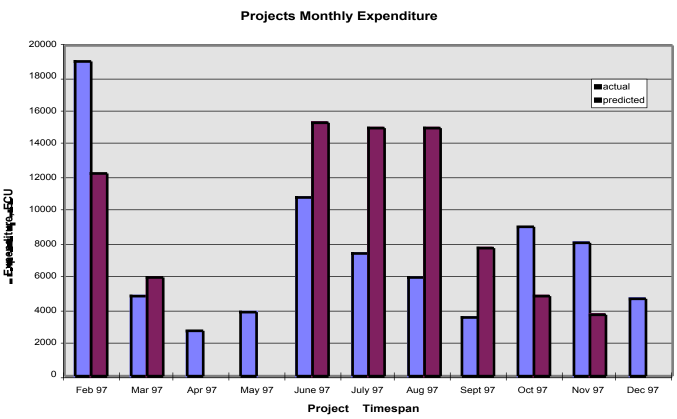
The Application Experiment had an approved budget of 80,000 ECU's which included an initial up-front payment of 20,000 ECU's (25%).

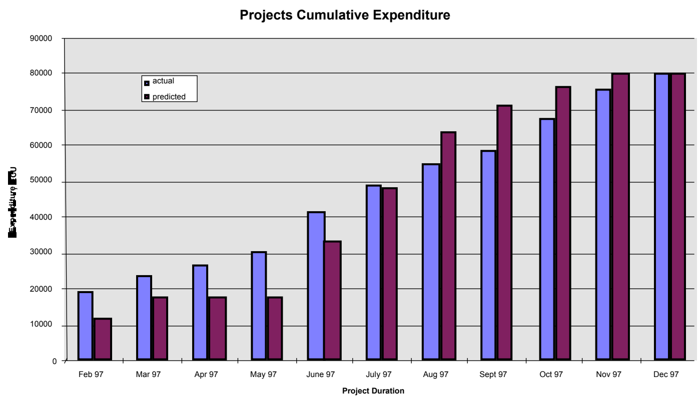
The initial payment was paid on 18 December 1996.

An additional payment of 30,000 ECU's was made in November 1997.

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 charts above, indicate:

- The predicted and actual monthly expenditure,
- The predicted and actual cumulative expenditure,

Specifically Chart 1 indicates the actual spend over months February ‘97 to December ‘97 and confirms the effort expended to complete the project within a practical time scale that accurately accounted for the predicted person days deemed for this technology transfer as planned.

At the end of March 97 it was decided to defer the CAD and Design training until after the sub-system level design had started, which would make it practical as well as theoretical. This accounts for the apparent 2 month lapse following the predicted monthly expenditure on the first chart, which then gave a better reflection of the work profile. Training was therefore on target with the next stage programmed during July 97.

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

The right hand chart shows the cumulative expenditure and the budget with all the figures in ECU's.

4.3 Subcontractor Information

Bolton Institute Technology Development Unit is part of the Institute of Higher Education and has been set up to develop Microelectronic Applications support for industrial research, development and technology transfer specialising in new materials, manufacturing processes and product development. The unit which was formed in 1992 is currently (1997) managing in excess of 3 million ECU's of research and development contracts mostly in UK.

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 technological-commercial team of expertise. The unit also provides access to public (i.e. DTI and EC grant-aided assistance) finance and specialise in training and are able to manage projects from the feasibility stage through to the design and prototype stage.

4.3.1 Role in the Application Experiment

The main support for the Application Experiment came from Bolton Institute TDU. They provided both management and technical expertise, without which the project would not have run so smoothly. Specifically they assisted us in the evaluation of a range CAD tools available on the market. After the selection they provided training in use of ’C’, with particular emphasis on ‘Good Design Practice’. They also provided all the technical input into the design of the component. Particular emphasis was placed on how to mix these technologies.

4.3.2 Subcontractor contribution

The Bolton Institute TDU, Microelectronics Design Centre, was responsible for the design of the microelectronic components of this Application Experiment. The TDU produced:

- The Functional, System and Technical specifications.
- DSP algorithms.
- Sampling and data processing strategies.
- Sourced the components used in the design.
- Designed the microelectronic hardware.
- Produced the circuit schematics using EDWIN CAD system.
- Designed the software for both the microelectronic boards using In Circuit Emulation (ICE) techniques and programmed the system in the ANSI ‘C’ high level language.
- Evaluated the design using a test rig of switch inputs and LED relay driven outputs.

- Produced all the system documentation, for presentation to Castle Group Limited to assist them in gaining a full understanding of the system structure and performance.

The documentation included:

- Functional, system and technical specifications.
- Circuit diagrams.
- Sample boards fully populated and working to the agreed specifications.
- Design notes.
- Software listings and disk containing source and compiled code.

The TDU Microelectronics provided the training course in addition to working with the staff of Castle Group Limited during the specification and design phases of the Application Experiment.

The following courses were delivered to the company:

- Introduction to managing and specifying microcontroller projects.
- Introduction to managing and specifying ASIC projects
- ANSI C course
- Use of ANSI C on microcontrollers.
- Introduction to DSP systems.
- Use of MATLAB and Simulink.

4.4 Castle Group Ltd Role in the Application Experiment

The main role of Castle Group was as Project Leader.

Castle also provided Technical Project Management, information on the existing product, development of specifications, the modification of circuit designs within their current capabilities to suit the new technology and testing and reporting.

Castle was the recipient of the technology transfer programme and has acquired the knowledge and skills to implement projects using FPGA and DSP processors. Castle also assisted in the later stages of the system design, implementation and testing in conjunction with Bolton.

Castle spent 320 man-days on the project and an exact breakdown of the effort for each task is given in the workplan at 4.1. Castle spent a considerable amount of time on the instrument specification after the initial training to ensure a correct starting point for the electronic design. Castle’s input to the electronic design was to produce all the analogue input circuitry, which was already within the company’s engineers’ expertise, and to assist the main subcontractor with the DSP design at the same time as taking on the knowledge for replication.

Castle’s software engineer was responsible for defining the algorithms and for the menu structure for the display.

A second subcontractor, originally called Blue Fuse Product Design but since changed their name to Lycett Design, was directly under the control of the first user for the mechanical design and production of engineering drawings for a prototype enclosure for the finished product. A prototype space model was also produced to prove that the circuits could be incorporated into an enclosure suitable for future manufacture and sale.

5. RESULTS

5.1 Monitoring

During the course of the Application Experiment, which extended from September 1996 to December 1997, monthly monitoring reports were completed which helped to identify any problems early on so that solutions could be worked on. The monthly reports enhanced communication throughout the experiment.

The planning and specification were complete by October 1997.

Specification

The Instrument Functional Specification was developed by Castle Group Limited and the Technology Development Unit (TDU) of Bolton Institute and was agreed on 2 October 1997. The basic specifications of the application experiment are referred to in section 2, they were not completed on time but together with the help of the subcontractor have resulted in a much higher specification with in-built flexibility and future designs in mind.

Training

Training was completed during June and July 1997

Courses were attended by two staff on:

- ANSI ‘C’
- Introduction to DSP
- DSP system and structures
- Use of Simulink and MATLAB
- Microcontroller Design

By August 1997 training was complete and familiarity with the new design packages and its application to the specific design was well in hand.

Design

During the design phase of the Application Experiment undertaken during September - December 1997 some introductory skills were acquired for:

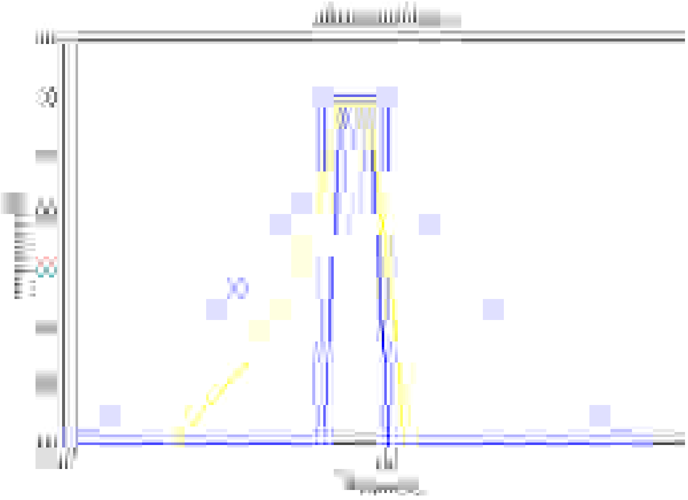
1. Use of DSP TMS 320 tools,
2. 16-Bit Microcontroller ‘C’ programming skills,
3. Use of ICE Tools, and
4. XILINX FPGA Hardware design skills

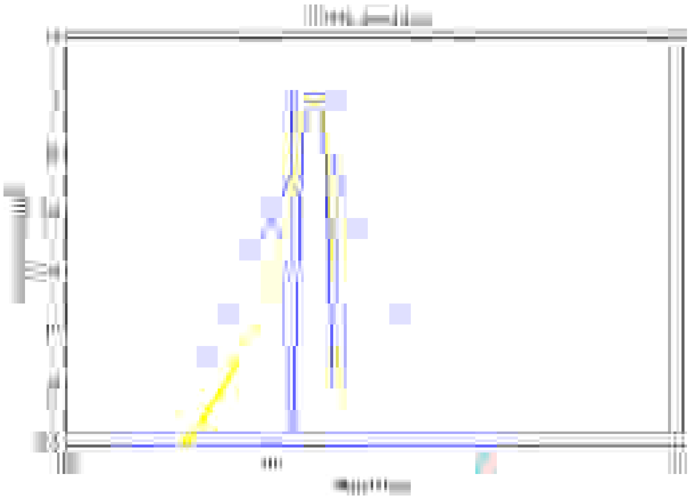
December 1997 saw the completion of the system and subsystem design.

Evaluation

Prototype construction and testing was completed in January 1998 but with the on-going functional and field testing outstanding.

The figures below illustrate the frequency response of octave bandpass filters implemented using DSP techniques. The area between the inner and outer bands is the region of the desired frequency response. This response conforms to the analogue standard specifications for sound level measurement instruments as outlined in the system specification. The original instrument would take some 2 minutes with the aid of an operator controlling the instrument to achieve the results data for the 11 required 1/1 octaves. This DSP section of the instrument can analyse the input signals, process the data and pass it to the 16 bit microcontroller section of the instrument for post processing and display in some 40 msec. This is done by a simple operator command to start working with a given set of filter characteristics. The resultant data can be displayed on the LCD display as shown below, data logged and/or sent to external printers and interfaces to IBM PCs.





5.2 Specific 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 Castle Group Limited.

2. Formal project planning, management and control has been shown to work, and will be applied to future 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.

6. 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 - Castle Group Ltd have gained considerable technical knowledge and experience in the use of DSP and FPGA technology. Castle in-house electronics and software engineers have been trained in the use of DSP processors and FPGAs which will enable the technology to be incorporated into future designs. The use of DSP and algorithm techniques into the new product has increased the security of the product.

2. Advanced 16 bit microcontrollers - Castle Group Ltd. Have experience in the use of 8 bit microcontrollers in their current range of products. This component had insufficient processing power and the software was written in assembler language. To improve the performance the company, has with TDU assistance, selected a new 16 bit microcontroller to take the company forward into the development of new products. The company can now use In Circuit Emulation techniques and write/debug the software using the high level language ANSI C.

3. Heightened Confidence - These new technical abilities have created the confidence to seek new markets, where we can offer this all round expertise.

4. Enhanced Sales - Castle Group Ltd have identified new markets directly as a result of being able to offer an enhanced functionality instrument with simpler use interfaces.

5. Project Planning and Management - Formal project planning and management techniques were used throughout this project, with detailed work plans, deliverables, target dates, etc. The management of a major subcontractor in the development of a new product with new technology was of considerable benefit and use for future projects.

5.4 Resulting Product, its Industrialisation and internal replication

Castle retained the services of their main subcontractor after the official end of the experiment to assist them in putting together the final prototype.

Castle have now invested in 3D CAD design and tooling to produce engineering drawings for a plastic injection mould tool for the a new enclosure for the product enclosure. A picture of the first prototype is shown below.

Several prototypes of the product have now been produced and marketing is in hand. A large overseas sale has been won for this advanced specification instrument.

Castle Group Ltd have commenced work on the design of a further new product, to be available for delivery during the early part of 1999, which will use the new technology. As a direct result of this project Castle have doubled the size of the workforce in the electronics design laboratory and a further software engineer will be hired before the end of the new development.

Prototype enclosure

5.5 Economic impact and improvement in competitive position

The experiment has resulted in an advanced product that has very much superior facilities and features and not the same as the existing product nor a direct replacement for it. A direct comparison of costs is therefore impossible.

It was considered, because the capabilities of the new technology were so much greater than the existing, that it would be much more appropriate to incorporate new features into the design than to re-engineer the original.

Although the costs are difficult to compare it is considered that if the existing product were re-engineered the cost would be reduced.

In volume production the new product costs are estimated to be 5% lower than the existing product although the new product has all the features outlined in the appropriate section 2.4

We anticipate that turnover will increase by 100% over a two year period representing a substantial increase in market share and profits. On the basis of this, as explained in the last section we have already increased our work force to cope with the expected sales.

However, the costs of the new product in production are estimated to be 5% lower than existing but more importantly turnover will increase by 100% over a two year period representing a substantive increase in market share and profits.

The increased capabilities will enable the system to be applied to a much wider market, i.e. environmental monitoring as well as industrial vibration testing and certification. With new legislation, the noise and vibration measurement instrumentation market is expected to grow annually by 9% with much of the growth biased towards higher end specification instruments.

6. DISSEMINATION

6.1 Target Audience

The target audience for FUSE information, as shown previously, consists of SME's in the industrial control/automation/data acquisition sector.

- Specifically small companies with some 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 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

In addition to the funding for the microelectronic development by FUSE Castle Group Ltd have made a significant investment in the instrument housing, an early space module is shown earlier.

The company have researched the market to establish acceptable physical and aesthetic characteristics. The housing is to be made with a plastic injection mould. They have used rapid prototyping injection moulding techniques to develop the housing. Space models of the enclosure have been developed to determine component placement of the all elements, e.g. boom microphone, keyboard, LCD display, battery compartments, main electronic PCB, interface connector panel, etc.

To maximise the investment made in the development of the housing, the housing will be used to provide a new product image for Castle Group Ltd. New instruments, which will use major elements of the microelectronics developed under the FUSE AE, will be developed subsequent to the successful completion of this AE.

Before the end of the project an opportunity arose to tender for a large export government contract which would need to utilise the new technology. As a result of this experiment and the knowledge transfer, Castle Group were able to participate in this tender and have been successful.

The new product design is now under way and delivery will be made early in 1999.

6.3 Documents Available

The following publications have resulted from the Application Experiment:

- Article for European FUSE Newsletter.
- Article for the TTN 'In Touch' Bulletin.
- Demonstration and FUSE presentation at Information Society Technologies (IST) in Vienna Decemebr 1998.
- A Flyer has been produced which highlights the product and the involvement of Castle Group Ltd in the FUSE programme.

7. CONCLUSIONS

7.1 FUSE Programme

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

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.

During the training phases and the development of the product specifications significant technology transfer took place between the sub contractor (Bolton Institute TDU) and Castle Group Ltd. This transfer continued through the design and evaluation phases. As a consequence Castle Group Ltd are now in a strong position to assess future products and determine a realistic development strategy. Castle Group Ltd. will be able to make informed decisions on the use of human resources, whether they be internal or external (sub contractors), to achieve an optimal development cycle for new products.

Castle Group are now, as a result of this FUSE experiment, able to undertake future DSP and FPGA design work in house.

A more detailed sub-contractor contract and design workplan would have avoided some delays but the FU was fortunate in using a dedicated sub-contractor without whom further problems may have arisen.

7.2 Product

The primary new product as a result of this AE is the Castle Group Ltd. Digital Real Time Sound Level and Vibration Meter.

New business is dependent on the use of the new technologies chosen and could not have been achieved without FUSE assistance.

7.3 Company Personnel

The following, Castle-Group, staff have been involved with this AE:

- Mr P Bull - Managing Director.
- Mr P Hudson - Project Manager and Director.
- Mr M Davison - Chief design engineer.
- Mr A Simpson - Software engineer.

7.4 Profits

As a result of this AE, the number of units sold, turnover and profit are anticipated to grow to the figures indicated in Company Markets, section 1.5 of the Company Information.

As indicated in the Replication section, the housing and the microelectronic improvement in performance, coupled with the enhanced capabilities and knowledge of Castle Group Ltd staff as a consequence of this AE, will be greatly improved and further products will enhance the predicted growth in company profits solely associated with this project.